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2,5:3,4-DIANHYDRO-1,6-DIDEOXY-6-(TRIMETHYLAMINO)-D-ALLITOL AND -D-GALACTITOL*

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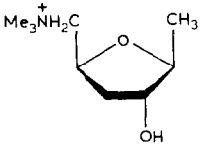
ABSTRACT

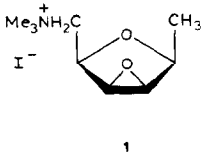
A new, four-step synthesis of 2,5:3,6-dianhydro-1-deoxy-D-glucitol **16** was worked out, starting from 1,6-dibromo-1,6-dideoxy-D-mannitol. Compound **16** was converted into different 4-*O*-acyl derivatives, the 3,6-anhydro rings of which where opened with hydrogen bromide, yielding the corresponding 6-bromo compounds. These were converted, *via* the 6-azides, into the 6-(dimethylamino) derivatives, the sulfonic esters of which gave, on treatment with base, the 2,5:3,4-dianhydro-D-allitol and -D-galactitol derivatives. These were converted with methyl iodide into the corresponding quaternary salts. On biological testing, only the D-allitol derivative showed weak, muscarine-like activity.

INTRODUCTION

In a previous study, the synthesis of muscarine analogs differing from muscarine in the presence of one or two additional hydroxyl groups, as well as in the configuration of C-3, was described[1]. As these compounds possessed no muscarine-like biological activity, the synthesis of two epoxides, the D-galactitol **1** and the D-allitol derivative **2**, was decided on.



Muscarine



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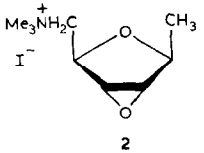

2

RESULTS AND DISCUSSION

For the synthesis of both **1** and **2**, 2,5:3,6-dianhydro-1-deoxy-D-glucitol (**16**) was chosen as the starting material; it had been obtained earlier[1], in an 8-step synthesis starting from D-mannitol, in an overall yield of ~15%. For the synthesis of larger amounts of **16**, an alternative route was explored, using as the starting

*Synthesis of Muscarine Analogs, Part II. For Part I, see ref. 1.

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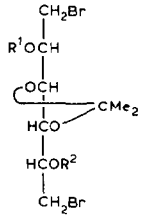
material the 3,4-*O*-isopropylidene derivative **3**, which can be readily obtained[2] from 1,6-dibromo-1,6-dideoxy-D-mannitol. Tosylation of **3** with one equivalent of tosyl chloride afforded a 3:1 mixture of the mono- (**4**) and di-tosylate (**5**) that could be separated by column chromatography, but, for the large-scale preparation of **16**, the mixture was boiled with conc. hydrochloric acid in ethanol. When this reaction was interrupted after 45 min (when all of the starting material had been consumed), a complex mixture was obtained that contained, besides the mono- (**6**) and di-tosyl ester (**7**), the desired 2,5-anhydro derivative **10** as only a minor component*. The different behavior of dibromide **4** compared to its 1,6-dibenzoate analog (which was completely converted into the corresponding 2,5-anhydride under identical conditions[1]) must be due to the presence of the terminal bromine atoms. When the reaction time was prolonged to 2 h, compound **4** was converted into the 2,5-anhydride **10**, but, simultaneously, bromine was partly replaced by chlorine at C-6, yielding the bromo-chloro compound **11**. In t.l.c., the latter had an R_F value identical with that of dibromide **10**, but, on treatment with sodium methoxide in methanol, compound **10** was readily converted into dianhydride **12**, whereas **11** remained mostly unchanged, the chlorine being a weaker leaving-group than bromine. This could also be proved experimentally, as **11** could be converted into dianhydride **12** under more-forcing conditions, simultaneously excluding the location of chlorine at C-1 (which should give the 1-chloro-dianhydride **13**).

To avoid these complications, the hydrolysis of crude **4** was conducted in the presence of conc. hydrobromic acid; the 1,6-dibromo-D-mannitol formed, and the ditosylate **7**, were separated from the mixture by crystallization and recrystallization, and the crude 2,5-anhydride **10** remaining was, without purification, converted with methanolic sodium methoxide into dianhydride **12**. During the latter reaction, the contaminating **7** gave diepoxide **9**, and unchanged monotosylate **6** was converted into diepoxide **8**, both being readily separated by column chromatography** from **12**. Reduction of bromide **12** with lithium aluminum hydride, a method which gave the 1-deoxy compound **16** in excellent yield in the case of the analogous 1-tosylate[1], was unsuccessful, and therefore the "hydrogen-transfer" method[3] was applied. A solution of **12** in boiling ethanol was treated with hydrazine hydrate as the hydrogen donor in the presence of Raney Ni, affording **16** in excellent yield (92%). When this four-step synthesis was performed without purification of the intermediates, the overall yield of **16** was ~50%.

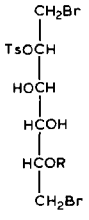
For obtaining the *galacto* 3,4-epoxide **1**, a proper leaving-group had to be introduced at C-4 into dianhydride **16**; therefore, **16** was converted into the known[1,4] 4-tosylate **17**. The 3,6-anhydro ring of this compound was split with hydrogen bromide in acetic acid–acetic anhydride, giving the acetylated bromide

*In t.l.c. **6** and **10** gave spots having identical R_F values, and even their m.p. values were very similar; consequently, their mixture was analyzed by ^{1}H-n.m.r. spectroscopy.

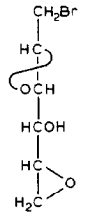
Compound **12 could also be purified *via* its 4-*p*-nitrobenzoate **14**, which crystallizes readily and can be deacylated with methanolic sodium methoxide.



3 $R^1 = R^2 = H$
4 $R^1 = Ts, R^2 = H$
5 $R^1 = R^2 = Ts$



6 R = H
7 R = Ts



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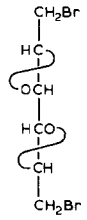

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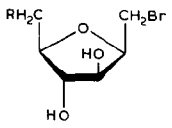
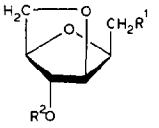
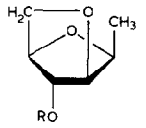


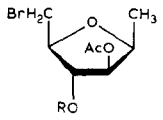
10 R = Br
11 R = Cl



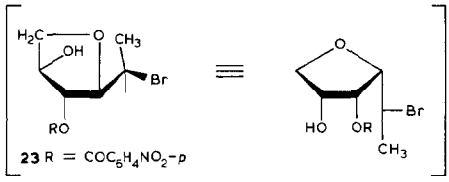
12 $R^1 = Br, R^2 = H$
13 $R^1 = Cl, R^2 = H$
14 $R^1 = Br, R^2 = COC_6H_4NO_2\text{-}p$
15 $R^1 = Br, R^2 = Ms$



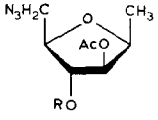
16 R = H
17 R = Ts
18 R = Ms
19 R = $COC_6H_4NO_2\text{-}p$



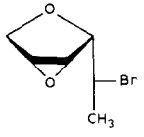
20 R = Ts
21 R = Ms
22 R = $COC_6H_4NO_2\text{-}p$



23 R = $COC_6H_4NO_2\text{-}p$



24 R = Ts
25 R = Ms
26 R = $COC_6H_4NO_2\text{-}p$



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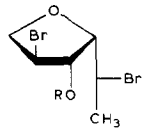


28
R = $COC_6H_4NO_2\text{-}p$

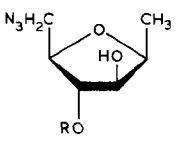
20. The terminal bromine atom in **20** was exchanged with sodium azide in *N,N*-dimethylformamide, yielding the 6-azide **24**. As on reduction of the azido group a simultaneous *O*→*N* acetyl migration can occur[5], **24** had to be deacetylated. To preclude the formation of a 3,4-epoxide, basic conditions had to be avoided, and

therefore this reaction was performed with methanolic hydrogen chloride. The hydroxy derivative **29** obtained gave, on reduction in the presence of hydrochloric acid, with Pd/C as the catalyst, the syrupy hydrochloride **32**. When the free base was liberated, this proved to be unstable, as *p*-toluenesulfonic acid was immediately eliminated, and only the crystalline epoxide **34** could be separated as its tosylate. Attempts to convert **34** into the dimethylamino derivative **36** with formaldehyde–formic acid were unsuccessful, as the oxirane ring was simultaneously split.

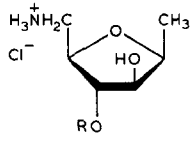
In further experiments, the mesyloxy group was used as leaving group at C-4; this had the benefit that most of the derivatives were crystalline compounds. First, the 1-bromo-dianhydride **12** was mesylated, and the ester **15** obtained was treated with hydrazine hydrate in the presence of Raney Ni, affording the 1-deoxy compound[4] **18** in high yield. This proved that the "hydrogen-transfer" method[3] can be successfully applied for the reduction of bromine, even in the presence of secondary mesyloxy groups (which are not attacked under these conditions). Mesylate **18** was converted, analogously to the tosylate **17**, *via* **21**→**25**→**30** into the 6-amino hydrochloride **33**. The latter was converted into dimethylamide **35** with formaldehyde–formic acid, and **35** gave, on treatment with sodium methoxide, the *galacto*-epoxide **36**. Methylation of **36** with methyl iodide afforded the quaternary salt **1** as an amorphous solid material.

For the synthesis of the analogous D-*allo* isomer **2**, the 4-hydroxyl group of **16** had to be blocked by a group that resists treatment with hydrobromic acid, but can be removed with base. Accordingly, **16** was converted into its 4-*p*-nitrobenzoate **19** which, on treatment with hydrobromic acid in acetic acid–acetic anhydride, gave the expected 6-bromide **22** as the main component and a small proportion of a by-product, tentatively assigned the structure of anhydro-dibromide **28**, which could be separated by column chromatography. Support for the proposed *trans* relationship of the groups at C-4 and C-5 was obtained experimentally, as treatment of **28** with an excess of methanolic sodium methoxide afforded the epoxide **27**. This could not be separated from the accompanying methyl *p*-nitrobenzoate, but ^{1}H- and ^{13}C-n.m.r.-spectral investigation of the mixture proved unambiguously the presence of the oxirane ring.

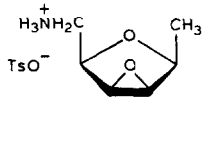
The 6-bromide **22** was converted, *via* the 6-azido-acetate **26**, into the crystalline 3-hydroxy compound **31**, which gave, on tosylation, the mixed ester **37**. Treatment of the latter with methanolic sodium methoxide afforded the D-*allo* epoxide **38**, which was hydrogenated over Pd/C as the catalyst. Instead of the expected 6-amino derivative **39**, a mixture of several compounds was obtained, due probably to attack on the oxirane ring by the amino group formed, yielding, in part, a 3,6-imino derivative, and in part, polymeric products. This reaction could not be prevented by conducting the reduction in the presence of acid, as this promoted the hydrolytic cleavage of the oxirane ring. To avoid these side-reactions, the oxirane ring in azide **38** was opened with hydrochloric acid, yielding an ~1:1 mixture of the corresponding 2- and 3-chloro isomers **41** and **44**. This mixture was then hydrogenated in the presence of hydrochloric acid over Pd/C, affording a mixture



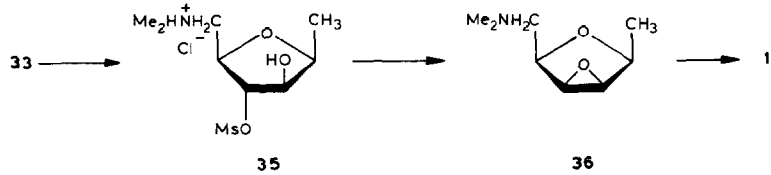
29 R = Ts
30 R = Ms
31 R = $COC_6H_4NO_2$-*p*



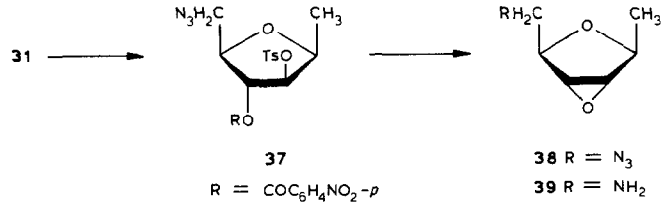
32 R = Ts
33 R = Ms



34

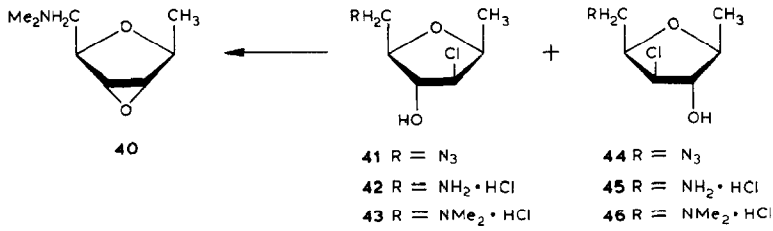


35 36



37
R = $COC_6H_4NO_2$-*p*

38 R = N_3
39 R = NH_2



40

41 R = N_3
42 R = $NH_2 \cdot HCl$
43 R = $NMe_2 \cdot HCl$

44 R = N_3
45 R = $NH_2 \cdot HCl$
46 R = $NMe_2 \cdot HCl$

of **42** and **45**, which, without separation, was methylated with formaldehyde–formic acid. The 6-(dimethylamino) isomers **43** and **46** so obtained were treated at an elevated temperature with an excess of methanolic sodium methoxide, affording epoxide **40** as a single product. Treatment of the latter with methyl iodide gave the crystalline, quaternary salt **2**.

On biological testing, the D-*galacto* isomer **1** showed no muscarine-like activity, whereas the D-*allo* isomer **2** was active, but only at doses of 100 mg/kg. (Muscarine showed the same activity at a dose of 1 mg/kg.) These data suggest that

muscarine possesses a highly stereospecific biological activity, and the (published) similarly strong effect of D- and L-muscarone (the 3-keto derivative of muscarine) must have a cause different from the structural similarity suggested[6].

EXPERIMENTAL

General methods. — After organic solutions had been dried with sodium sulfate, all evaporations were conducted in a rotary evaporator under diminished pressure. Light petroleum had b.p. 60–80°. Optical rotations were determined for solutions in chloroform (*c* 1), if not stated otherwise. T.l.c. was effected on Kieselgel G with (*A*) ethanol, (*B*) 9:1 ethanol–conc. ammonium hydroxide, (*C*) 5:1 ethanol–ethyl acetate, and ethyl acetate–carbon tetrachloride 1:1 (*D*), 1:3 (*E*), 1:5 (*F*), and 1:9 (*G*). For detection, 1:1 0.1M potassium permanganate–M sulfuric acid was used at 105°. Column chromatography was performed on Kieselgel 40 (63–200 μm). ^{13}C-N.m.r. spectra (25.2 MHz) and ^{1}H-n.m.r. spectra (90 MHz) were recorded at room temperature with respectively a Varian XL-100 FT and a Varian EM 390 spectrometer, for solutions in (*a*) chloroform-*d*, with tetramethylsilane as the internal standard, (*b*) D_2O, or (*c*) dimethyl sulfoxide-d_6, with sodium 4,4-dimethyl-4-silapentane-1-sulfonate as the internal standard.

2,5:3,4-Dianhydro-1,6-dideoxy-6-(trimethylamino)-D-*galactitol iodide* (**1**). — To a solution of epoxide **36** (0.5 g) in acetone (10 mL) was added methyl iodide (0.5 mL), and the mixture was kept overnight at room temperature, and then evaporated. The residue was purified by filtering through a short column with the aid of ethanol. The fractions having R_F 0.2 gave, on evaporation, a yellow syrup which was dissolved in water, filtered (charcoal), and freeze-dried to give **1** as a pale yellow, amorphous solid (0.5 g, 53%); ^{1}H-n.m.r. data (*b*): δ 4.4–3.5 (m, H-2,3,4,5,6), 3.22 (s, N-Me_3), and 1.40 (d, H-1).

Anal. Calc. for $C_9H_{18}INO_2$: C, 36.13; H, 6.06; I, 42.42; N, 4.68. Found: C, 35.92; H, 6.25; I, 42.10; N, 4.59.

2,5:3,4-Dianhydro-1,6-dideoxy-6-(trimethylamino)-D-*allitol iodide* (**2**). — To a solution of epoxide **40** (1.6 g) in acetone (10 mL) was added methyl iodide (1.5 mL). The precipitated crystals were filtered off, and washed with acetone, to give pure **2** (2.2 g, 73.5%); m.p. 162–164°, $[\alpha]_D^{20}$ +23° (water); ^{1}H-n.m.r. data (*b*): δ 4.30 (q, H-2), 3.90 (m, H-3,4), 3.50 (m, H-5,6), 3.20 (s, N-Me_3), and 1.27 (d, H-1).

Anal. Calc. for $C_9H_{18}INO_2$: C, 36.13; H, 6.06; I, 42.42; N, 4.68. Found: C, 36.13; H, 6.13; I, 42.17; N, 4.72.

1,6-Dibromo-1,6-dideoxy-3,4-O-*isopropylidene-2*-O-p-*tolylsulfonyl-* (**4**) *and -2,5-di*-O-p-*tolylsulfonyl*-D-*mannitol* (**5**). — To a stirred solution of 1,6-dibromide[2] **3** (230 g) in dry pyridine (900 mL) was added gradually a solution of *p*-toluenesulfonyl chloride (164 g) in dry pyridine (200 mL) during 1 h at 10°. Thereafter, the mixture was kept for 5 h at room temperature, and then poured into water. The precipitated oil was extracted with chloroform, and the extract processed in the

usual way, to give, after evaporation, an oil (340 g) containing, besides unchanged starting material (**3**), the two tosylated derivatives **4** and **5**. An aliquot (5 g) of this mixture was separated by column chromatography (*G*). The fractions having R_F 0.60 gave, on evaporation, ditosylate **5** as a syrup (1.1 g, 22%); $[\alpha]_D^{20}$ −28°; ^{1}H-n.m.r. data (*a*): δ 7.80 and 7.30 (d,d, tosyl), 4.60 (m, H-2,5), 4.15 (m, H-3,4), 3.60 (m, H-1,6), 2.35 (s, tosyl-Me), and 1.30 (s, CMe_2).

Anal. Calc. for $C_{23}H_{28}Br_2O_8S_2$: Br, 24.34; S, 9.76. Found: Br, 24.05; S, 9.50.

The fractions having R_F 0.50 gave, on evaporation, monotosylate **4** as a syrup (3.2 g, 64%); $[\alpha]_D^{20}$ +10°; ^{1}H-n.m.r. data (*a*): δ 7.90 and 7.28 (d,d, tosyl), 4.88 (q, H-2), 4.42 (t, H-5), 3.62 (d, H-1,6), 2.6 (d, OH), 2.46 (s, tosyl-Me), and 1.35 (CMe_2).

Anal. Calc. for $C_{16}H_{22}Br_2O_6S$: Br, 31.82; S, 6.38. Found: Br, 31.95; S, 6.49.

*1,6-Dibromo-1,6-dideoxy-2-*O*-p-tolylsulfonyl-*D*-mannitol* (**6**). — A solution of **4** (2.5 g) in ethanol (30 mL) and conc. hydrobromic acid (3 mL) was boiled for 30 min and cooled. The solution was made neutral with sodium hydrogencarbonate to give, after filtration and evaporation, a semisolid residue. Recrystallization from ether–light petroleum gave pure **6** (1.1 g, 47.8%); m.p. 113–115°, $[\alpha]_D^{20}$ −12° (acetone): R_F 0.50 (*D*); ^{1}H-n.m.r. data (*a*): δ 7.90 and 7.41 (d,d, tosyl), 4.80 (m, H-2), 4.00 (m, H-1,3,4,5), 3.00 (s, 2 OH), 2.60 (s, OH), and 2.50 (s, tosyl-Me).

Anal. Calc. for $C_{13}H_{18}Br_2O_6S$: C, 33.78; H, 3.92; Br, 34.58; S, 6.93. Found: C, 33.60; H, 4.05; Br, 34.76; S, 6.85.

*1,6-Dibromo-1,6-dideoxy-2,5-di-*O*-p-tolylsulfonyl-*D*-mannitol* (**7**). — A solution of **5** (0.6 g) in ethanol (10 mL) and conc. hydrobromic acid (1 mL) was boiled for 5 h. On cooling, fine needles separated; these were filtered off, and washed with ethanol, to yield pure **7** (0.37 g, 65.7%); m.p. 177–179°, $[\alpha]_D^{20}$ −41°; R_F 0.70 (*D*); ^{1}H-n.m.r. data (*a*): δ 7.88 and 7.33 (d,d, tosyl), 4.70 (m, H-2,5), 4.00 (m, H-3,4), 3.60 (m, H-1,6), and 2.48 (s, tosyl-Me).

Anal. Calc. for $C_{20}H_{24}Br_2O_8S_2$: C, 38.97; H, 3.91; Br, 25.93; S, 10.40. Found: C, 38.72; H, 3.90; Br, 26.00; S, 10.56.

Hydrolysis with hydrochloric acid of the mixture obtained on tosylation of **3**. — A solution in ethanol (1.5 L) and conc. hydrochloric acid (150 mL) of the syrupy mixture (153 g) obtained on tosylation of **3** (105 g) was boiled for 2 h. The cooled solution was made neutral with solid sodium hydrogencarbonate, the precipitated salts were filtered off, and the filtrate was evaporated. The residue was partitioned between ethyl acetate and water, and the organic solution was dried and evaporated. The semisolid residue was filtered with the aid of ether, and washed with ethyl acetate, to yield 1,6-dibromo-1,6-dideoxy-D-mannitol (7.9 g, 8.6%); R_F 0 (*D*), 0.8 (ethyl acetate). The combined filtrate was evaporated, and the residue filtered with ether, to yield crude ditosylate **7** (14 g, 7.6%). The filtrate was evaporated, to yield a semisolid residue (67 g, 76%) containing the 2,5-anhydride **10** as the main component, besides its 6-chloro analog **11**, and the mono- **6** and the di-tosylate **7**. This mixture was converted, without purification, into dianhydride **12**.

Hydrolysis with hydrobromic acid of the mixture obtained on tosylation of **3**.

— A solution in ethanol (3 L) and conc. hydrobromic acid (300 mL) of the syrupy mixture (300 g) obtained on tosylation of **3** (230 g) was boiled for 3 h. The solution was processed as described for the hydrolysis with hydrochloric acid, to give 1,6-dibromo-1,6-dideoxy-D-mannitol (27.9 g, 13.7%), ditosylate **7** (40.6 g, 9.4%), and a semisolid residue (130 g, 68%), containing mainly anhydride **10**. An aliquot (5 g) was twice recrystallized from ether–light petroleum, to give pure **10** (4.1 g, 56%); m.p. 118–121°, $[\alpha]_D^{20}$ +14.5° (acetone); R_F 0.5 (*D*); ^{1}H-n.m.r. data (*c*): δ 5.36 and 5.32 (d,d, 2 OH), 4.15 (m, H-5), 3.85 (m, H-2,3,4), and 3.50 (m, H-1,6); ^{13}C-n.m.r. data (*c*): δ 87.4 and 83.7 (C-2,5), 81.4 and 78.3 (C-3,4), 35.8 (C-6), and 32.8 (C-1).

Anal. Calc. for $C_6H_{10}Br_2O_3$: C, 24.85; H, 3.47; Br, 55.11. Found: C, 25.01; H, 3.43; Br, 55.16.

*2,3:5,6-Dianhydro-1-bromo-1-deoxy-*D*-glucitol* (**8**). — To a solution of monotosylate **6** (4.6 g) in methanol (20 mL) was added 4.4M methanolic sodium methoxide, and the mixture was kept for 2 h at room temperature. Thereafter, it was made neutral with solid carbon dioxide, and evaporated. The residue was dissolved in ethyl acetate, and the solution washed with water, dried, and evaporated. The residue was dissolved in ether, filtered (charcoal), and evaporated, to give **8** as a colorless oil (2 g, 98%); $[\alpha]_D^{20}$ −9°, R_F 0.4 (*D*); ^{1}H-n.m.r. data (*a*): δ 3.6–2.8 (m, H-1,2,3,4,5,6); ^{13}C-n.m.r. data (*a*): δ 69.5 (C-4), 60.4 (C-2), 54.3 (C-3), 52.0 (C-5), 44.6 (C-6), and 31.8 (C-1).

Anal. Calc. for $C_6H_9BrO_3$: C, 34.47; H, 4.33; Br, 38.22. Found: C, 34.52; H, 4.50; Br, 38.10.

*2,3:4,6-Dianhydro-1,6-dibromo-1,6-dideoxy-*L*-iditol* (**9**). — To a slurry of ditosylate **7** (3.1 g) in chloroform (15 mL) and methanol (5 mL) was added 5M methanolic sodium methoxide (2.5 mL). A clear solution was obtained, from which sodium *p*-toluenesulfonate separated. The mixture was washed with water after 1 h to give, after evaporation, a solid residue which on recrystallization from methanol afforded pure **9** (1.15 g, 84.6%); m.p. 107–108°, $[\alpha]_D^{20}$ −62° (acetone); lit.[2] m.p. 108–109°, $[\alpha]_D^{20}$ −56.1° (acetone).

*2,5-Anhydro-1-bromo-6-chloro-1,6-dideoxy-*D*-glucitol* (**11**) *and 2,5:3,6-dianhydro-1-bromo-1-deoxy-*D*-glucitol* (**12**). — *Method a.* A solution in methanol (130 mL) of crude **10** (67 g) obtained on hydrolysis with hydrochloric acid was treated with 5M methanolic sodium methoxide (40 mL). The mixture was kept for 4 h at room temperature, then made neutral with solid carbon dioxide. The residue obtained by evaporation was separated by column chromatography (*D*). The fractions having R_F 0.8–0.95 gave, on evaporation, a syrupy mixture (10.7 g) containing, among other compounds, diepoxide **6**.

The fractions having R_F 0.5 gave, on evaporation and subsequent recrystallization of the residue from ether–light petroleum, the chloro-bromo derivative **11** (3.4 g, 5.1%); m.p. 108–110°, $[\alpha]_D^{20}$ +38°; +24° (acetone); ^{1}H-n.m.r. data (*a*): δ 5.24 and 5.03 (d,d, 2 OH), 4.48 (m, H-5), 4.25 (m, H-2,3,4), 3.80 (m, H-1), and 3.70 (m, H-6).

Anal. Calc. for $C_6H_{10}BrClO_3$: C, 29.35; H, 4.10; Br, 32.55; Cl, 14.44. Found:

C, 29.42; H, 4.15; Br, 32.17; Cl, 14.30.

The fractions having R_F 0.35 gave, on evaporation and recrystallization of the residue from ether–light petroleum, dianhydride **12** (25 g, 51.8%)*; m.p. 93–96°, $[\alpha]_D^{20}$ +123.6°; ^{1}H-n.m.r. data (*a* + *c*): δ 4.80 (m, H-3,5), 4.35 (m, H-2), 4.05 (m, H-4,6), and 3.50 (m, H-1).

Anal. Calc. for $C_6H_9BrO_3$: C, 34.47; H, 4.33; Br, 38.22. Found: C, 34.51; H, 4.38; Br, 38.32.

Method b. To a solution of *p*-nitrobenzoate **14** (3.6 g) in chloroform (10 mL) and methanol (10 mL) was added 1 drop of M methanolic sodium methoxide. The reaction was complete within 1 h. The solution was then evaporated, and the residue freed of methyl *p*-nitrobenzoate by column chromatography (*D*). The fractions having R_F 0.5 gave, on evaporation, pure **12** (1.8 g, 86%), identical with that obtained *via* method *a*.

Method c. A solution of the bromo-chloro compound **11** (1.2 g) in methanol (20 mL) and 5M methanolic sodium methoxide (1 mL) was boiled for 2 h. The solution was cooled, made neutral with solid carbon dioxide, and evaporated. The residue was purified by column chromatography (*D*), to give **12** (0.7 g, 68%), identical with that obtained *via* method *a*.

*2,5:3,6-Dianhydro-1-bromo-1-deoxy-4-*O*-p-nitrobenzoyl-*D*-glucitol* (**14**). — To a stirred solution of dianhydride **12** (8.4 g) in pyridine (40 mL) was added *p*-nitrobenzoyl chloride (10 g). The temperature of the mixture rose to 50°. It was poured into water after 1 h at room temperature. The precipitated oil was extracted with chloroform, and the extract processed in the usual way to give, after recrystallization from methanol, pure **14** (8.9 g, 62%); m.p. 137–138°, $[\alpha]_D^{20}$ −17°; R_F 0.45 (*F*); ^{1}H-n.m.r. data (*a*): δ 8.20 (m, aromatic), 5.45 (d, H-4), 4.60 (m, H-3,5), 4.48 (t, H-2), 4.12 and 3.90 (d,d, H-6), and 3.60 (d, H-1); ^{13}C-n.m.r. data (*a*): δ 164.5 (CO), 150.5, 134.2, 131.0, and 123.7 (*p*-nitrobenzoate), 81.7 (C-5), 77.9 (C-3), 77.2 (C-4), 75.6 (C-2), 73.6 (C-6), and 28.7 (C-1).

Anal. Calc. for $C_{13}H_{12}BrNO_6$: C, 43.59; H, 3.37; Br, 22.31; N, 3.91. Found: C, 43.67; H, 3.77; Br, 22.40; N, 4.07.

*2,5:3,6-Dianhydro-1-bromo-1-deoxy-4-*O*-methylsulfonyl-*D*-glucitol* (**15**). — To a solution of bromide **12** (1 g) in pyridine (5 mL) was added mesyl chloride (1.5 mL), and the mixture was kept overnight at room temperature. Thereafter, it was processed in the usual way, to give, after recrystallization from ether–light petroleum and subsequently from methanol, pure **15** (1.1 g, 78.5%); m.p. 98–100°, $[\alpha]_D^{20}$ +61°; R_F 0.5 (*P*); ^{1}H-n.m.r. data (*a*): δ 5.15 (d, H-4), 4.60 (m, H-3,5), 4.46 (t, H-2), 4.06 and 3.80 (d,d, H-6), 3.56 (d, H-1), and 3.15 (s, mesyl-Me).

Anal. Calc. for $C_7H_{11}BrO_5S$: C, 29.27; H, 3.86; Br, 27.83; S, 11.16. Found: C, 29.14; H, 3.98; Br, 27.71; S, 11.23.

*2,5:3,6-Dianhydro-1-deoxy-*D*-glucitol* (**16**). — To a stirred solution of bromide **12** (21 g) in ethanol (200 mL) were added Raney Ni (50 g) and, sub-

*The yield was 75% when crude **10** obtained on hydrolysis with hydrobromic acid was used.

sequently, hydrazine hydrate (5 mL). An exothermic reaction and vigorous gas evolution occurred. When the mixture had cooled below the boiling point, further hydrazine hydrate (5 mL) was added, and this addition was repeated once more. Stirring was continued until the evolution of gas ceased. The cooled slurry was filtered, the Raney Ni was washed with ethanol, and the combined filtrates were evaporated. The residue was treated with ether–light petroleum, and the precipitated salts were filtered off. Evaporation of the filtrate gave semisolid **16** (12 g, 92.3%), pure enough for further experiments. Recrystallization from ethyl acetate–light petroleum afforded pure **16**; m.p. 79–81°, $[\alpha]_D^{20}$ +106.4° (water); lit.[1] m.p. 79–81°, $[\alpha]_D^{20}$ +105.5° (water); lit.[4] m.p. 80–81°, $[\alpha]_D^{20}$ +107.9° (water).

*2,5:3,6-Dianhydro-1-deoxy-4-*O*-methylsulfonyl-*D*-glucitol* (**18**). — A solution of mesylate **15** (6 g) in ethanol (60 mL) was treated with Raney Ni (6 g) and hydrazine hydrate (3 × 1 mL) as described for **16**. The filtered solution was evaporated, the residue dissolved in chloroform, and the solution washed with water, dried, and evaporated to give, after recrystallization from ether–light petroleum, pure **18** (3.4 g, 78%) containing ether as solvent of crystallization; m.p. 56–58°; R_F 0.4 (*D*); lit.[4] m.p. 58–60°.

*2,5:3,6-Dianhydro-1-deoxy-4-*O*-p-nitrobenzoyl-*D*-glucitol* (**19**). — To a solution of dianhydride **16** (5.2 g) in pyridine (50 mL) was added *p*-nitrobenzoyl chloride (10 g). The mixture was kept overnight at room temperature, and then poured into water. The precipitate was filtered off and washed with water to give, after recrystallization from ether–light petroleum, pure **19** (9.5 g, 85%); m.p. 114–116°, $[\alpha]_D^{20}$ +13.4°; R_F 0.55 (*E*); ^{1}H-n.m.r. data (*a*): δ 8.20 (m, aromatic), 5.36 (d, H-4), 4.40 (m, H-2,5), 4.05 and 3.90 (d,d, H-6), and 1.40 (d, H-1).

Anal. Calc. for $C_{13}H_{13}NO_6$: C, 55.91; H, 4.69; N, 5.02. Found: C, 55.83; H, 4.78; N, 4.95.

*3-*O*-Acetyl-2,5-anhydro-6-bromo-1,6-dideoxy-4-*O*-p-tolylsulfonyl-*D*-glucitol* (**20**). — A solution of dianhydro tosylate[1] **17** (2.9 g) in a mixture of acetic acid (30 mL) and acetic anhydride (3 mL) presaturated with hydrogen bromide was kept for 4 h at room temperature, and then poured into water. The precipitated syrup was extracted with chloroform to give, after the usual processing, crude **20** (4 g, 98%). An aliquot was purified by column chromatography (*E*). The fractions having R_F 0.7 gave, on evaporation, pure **20** as a syrup; $[\alpha]_D^{20}$ +4°; ^{1}H-n.m.r. data (*a*): δ 7.90 and 7.42 (d,d, tosyl), 5.22 (dd, H-4), 4.78 (dd, H-3), 4.15 (m, H-2,5), 3.49 (d, H-6), 2.48 (s, tosyl-Me), 2.06 (acetyl-Me), and 1.16 (d, H-1).

Anal. Calc. for $C_{15}H_{19}BrO_6S$: Br, 19.62; S, 7.86. Found: Br, 19.85; S, 7.70.

*3-*O*-Acetyl-2,5-anhydro-6-bromo-1,6-dideoxy-4-*O*-methylsulfonyl-*D*-glucitol* (**21**). — Dianhydro mesylate **18** (3.4 g) was treated with hydrogen bromide as described for **20**, to yield, after recrystallization from ether–light petroleum, pure **21** (4.35 g, 63%); m.p. 83–85°, $[\alpha]_D^{20}$ +12.6°; R_F 0.6 (*E*); ^{1}H-n.m.r. data (*a*): δ 5.18 (dd, H-4), 4.82 (dd, H-3), 4.20 (m, H-2,5), 3.52 (d, H-6), 3.13 (s, mesyl-Me), 2.12 (s, acetyl-Me), and 1.22 (d, H-1).

Anal. Calc. for $C_9H_{15}BrO_6S$: C, 32.63; H, 4.56; Br, 24.12; S, 9.68. Found: C, 32.55; H, 4.66; Br, 24.03; S, 9.50.

3-O-Acetyl-2,5-anhydro-6-bromo-1,6-dideoxy-4-O-p-nitrobenzoyl-D-glucitol (**22**) *and 3,6-anhydro-2,5-dibromo-4-O-p-nitrobenzoyl-L-gulitol* (**28**). — Dianhydro *p*-nitrobenzoate **19** (28 g) was treated with hydrogen bromide as described for **20**. The reaction was complete within 30 min, and the mixture was processed in the usual way to give a mixture of **22** and **28**, which was separated by column chromatography (*E*). The fractions having R_F 0.75 gave, on evaporation, crude **28** (3 g, 4.4%, m.p. 126–128°) which, after recrystallization from methanol, had m.p. 129–131°, $[\alpha]_D^{20}$ +37°; ^{1}H-n.m.r. data (*a*): δ 8.30 and 8.13 (d,d, aromatic), 5.73 (d, H-4), 4.35 (m, H-2,3,5,6), and 1.86 (d, H-1); ^{13}C-n.m.r. data (*a*): δ 163.3 (CO), 150.9, 134.5, 130.9, and 123.8 (*p*-nitrobenzoate), 83.7 and 80.9 (C-3,4), 75.7 (C-6), 47.8 (C-2), 43.4 (C-5), and 23.6 (C-1).

Anal. Calc. for $C_{13}H_{13}Br_2NO_5$: C, 36.90; H, 3.10; Br, 37.78. Found: C, 37.11; H, 3.25; Br, 39.32.

The fractions having R_F 0.65 gave, on evaporation, **22** as a syrup (35 g, 87%); $[\alpha]_D^{20}$ −36°; ^{1}H-n.m.r. data (*a*): δ 8.20 (m, aromatic), 5.40 (m, H-3,4), 4.40 (m, H-2,5), 3.62 (d, H-6), 2.17 (s, acetyl-Me), and 1.28 (d, H-1).

Anal. Calc. for $C_{15}H_{16}BrNO_7$: Br, 19.86; N, 3.48. Found: Br, 20.05; N, 3.19.

3-O-Acetyl-2,5-anhydro-1-azido-1,6-dideoxy-4-O-p-tolylsulfonyl-D-glucitol (**24**). — A solution of compound **20** (4.1 g) and sodium azide (1 g) in *N,N*-dimethylformamide (20 mL) and water (2 mL) was heated on a steam bath for 1 h. No difference in mobility was observed by t.l.c., but the spot changed color with time. The solution was cooled, and evaporated, and the residue was partitioned between chloroform and water. The organic solution was washed with water, dried, and evaporated to yield **24** as a pale yellow syrup (3.6 g, 97%); $[\alpha]_D^{20}$ +80.6° (acetone), R_F 0.70 (*E*); ^{1}H-n.m.r. data (*a*): δ 8.80 and 8.38 (d,d, tosyl), 5.16 (dd, H-4), 4.75 (dd, H-3), 4.15 (m, H-2,5), 3.56 and 3.20 (dd, dd, H-6), 2.43 (s, tosyl-Me), 2.03 (s, acetyl-Me), and 1.16 (d, H-1).

Anal. Calc. for $C_{15}H_{19}N_3O_6S$: N, 11.37; S, 8.68. Found: N, 11.20; S, 8.59.

3-O-Acetyl-2,5-anhydro-1-azido-1,6-dideoxy-4-O-methylsulfonyl-D-glucitol (**25**). — Compound **21** (3.3 g) was treated with sodium azide as described for **24** to yield **25** as a pale yellow syrup (2.8 g, 95%); $[\alpha]_D^{20}$ +153°; R_F 0.35 (*F*); ^{1}H-n.m.r. data (*a*): δ 5.12 (dd, H-4), 4.83 (dd, H-3), 4.20 (m, H-2,5), 3.60 and 3.32 (dd, dd, H-6), 3.12 (s, mesyl-Me), 2.15 (s, acetyl-Me), and 1.30 (d, H-1).

Anal. Calc. for $C_9H_{15}N_3O_6S$: N, 14.32; S, 10.93. Found: N, 14.06; S, 10.75.

3-O-Acetyl-2,5-anhydro-1-azido-1,6-dideoxy-4-O-p-nitrobenzoyl-D-glucitol (**26**). — Compound **22** (4 g) was treated with sodium azide as described for **24**, to yield, after recrystallization from methanol, pure **26** (3.2 g, 88%); m.p. 71–73°, $[\alpha]_D^{20}$ +39°; R_F 0.6 (*F*); ^{1}H-n.m.r. data (*a*): δ 8.20 (m, aromatic), 5.22 (d, H-3), 5.34 (d, H-4), 4.20 (m, H-2,5), 3.70 and 3.42 (dd, dd, H-6), 2.18 (s, acetyl-Me), and 1.31 (d, H-1).

Anal. Calc. for $C_{15}H_{16}N_4O_7$: C, 49.44; H, 4.42; N, 15.38. Found: C, 49.51; H, 4.45; N, 15.22.

3,6:4,5-Dianhydro-2-bromo-1,2-dideoxy-D-mannitol (**27**). — A solution of

dibromide **28** (2 g) in chloroform (10 mL) and methanol (5 mL) was made alkaline with 4M methanolic sodium methoxide in the presence of phenolphthalein. In t.l.c. the spot of the starting material (R_F 0.6; *F*) was rapidly converted, *via* a debenzoylated intermediate (R_F 0.45), into epoxide **27** (R_F 0.5). After 30 min, the solution was diluted with chloroform, washed with water, dried, and evaporated to give a solid residue (1.8 g) containing, according to n.m.r. investigations, epoxide **27** and methyl *p*-nitrobenzoate in the molar ratio of 1:1; $[\alpha]_D^{20}$ −66° (calculated on pure **27**); ^{1}H-n.m.r. data (*a*): δ 4.3–3.5 (m, H-2,3,4,5,6) and 1.73 (d, H-1); ^{13}C-n.m.r. data (*a*): δ 82.3 (C-3), 68.8 (C-6), 57.8 and 56.4 (C-4,5), 46.5 (C-2), and 23.3 (C-1).

*2,5-Anhydro-6-azido-1,6-dideoxy-4-*O-p-*tolylsulfonyl-*D-*glucitol* (**29**). — A solution of tosyl-azide **24** (9.4 g) in 1.5M methanolic hydrogen chloride (200 mL) was boiled for 45 min, cooled, and made neutral with solid sodium hydrogencarbonate; the precipitated salts were filtered off, the filtrate was evaporated and the residue partitioned between chloroform and water. The organic solution was washed with water, dried, and evaporated to yield **29** as a colorless syrup (7.6 g, 91.7%); $[\alpha]_D^{20}$ +56°; R_F 0.4 (*F*); ^{1}H-n.m.r. data (*a*): δ 7.78 and 7.32 (d,d, tosyl), 4.57 (d, H-4), 4.10 (m, H-2,3,5), 3.40 (m, H-6), 3.20 (s, OH), 2.42 (s, tosyl-Me), and 1.24 (d, H-1).

Anal. Calc. for $C_{13}H_{17}N_3O_5S$: N, 12.83; S, 9.79. Found: N, 12.51; S, 9.45.

*2,5-Anhydro-6-azido-1,6-dideoxy-4-*O-*methylsulfonyl-*D-*glucitol* (**30**). — Mesyl-azide **25** (3.3 g) was deacetylated with 1.5M methanolic hydrogen chloride (66 mL) as described for **29**. Recrystallization from ether–light petroleum gave pure **30** (2.4 g, 85%); m.p. 62–64°, $[\alpha]_D^{20}$ +74.4°; R_F 0.35 (*E*); ^{1}H-n.m.r. data (*a*): δ 4.75 (d, H-4), 4.10 (m, H-2,3,5), 3.60 (d, H-6), 3.02 (s, mesyl-Me), 2.70 (d, OH), and 1.32 (d, H-1).

Anal. Calc. for $C_7H_{13}N_3O_5S$: C, 33.45; H, 5.21; N, 16.72; S, 12.76. Found: C, 33.40; H, 5.29; N, 16.66; S, 12.69.

*2,5-Anhydro-6-azido-1,6-dideoxy-4-*O-p-*nitrobenzoyl-*D-*glucitol* (**31**). — Compound **26** (28 g) was deacetylated with 1.5M methanolic hydrogen chloride (560 mL) as described for **29**. Recrystallization from acetone–light petroleum gave pure **31** (21.7 g, 87.6%); m.p. 82–84°, $[\alpha]_D^{20}$ +44°; R_F 0.25 (*F*); ^{1}H-n.m.r. data (*a*): δ 8.2 (m, aromatic), 5.05 (d, H-4), 4.10 (m, H-2,3,5), 3.72 (d, H-6), 2.80 (d, OH), and 1.30 (d, H-1).

Anal. Calc. for $C_{13}H_{14}N_4O_6$: C, 48.44; H, 4.37; N, 17.38. Found: C, 48.48; H, 4.52; N, 17.12.

*6-Amino-2,5-anhydro-1,6-dideoxy-4-*O-*methylsulfonyl-*D-*glucitol hydrochloride* (**33**). — A solution of mesyl-azide **30** (2.5 g) in ethanol (25 mL) and M methanolic hydrogen chloride (10 mL) was hydrogenated in the presence of 10% Pd/C (0.5 g) as catalyst for 4 h at room temperature, filtered, the filtrate evaporated, and the solid residue filtered with ether to give pure **33** (2.5 g, 96%); m.p. 159–160°, $[\alpha]_D^{20}$ +25° (water); R_F 0.8 (*B*); ^{1}H-n.m.r. data (*b*): δ 4.95 (d, H-4), 4.35 (m, H-2,5), 3.40 (m, H-6), 3.31 (s, mesyl-Me), and 1.28 (d, H-1).

Anal. Calc. for $C_7H_{16}ClNO_5S$: C, 32.12; H, 6.16; Cl, 13.54; N, 5.35; S, 12.25. Found: C, 32.00; H, 6.35; Cl, 13.42; N, 5.21; S, 12.14.

*6-Amino-2,5:3,4-dianhydro-1,6-dideoxy-*D*-galactitol* p-*toluenesulfonate* (**34**). — Tosyl-azide **29** (3.3 g) was hydrogenated as described for **33**. The reduction was complete within 24 h. The suspension was filtered, the filtrate evaporated, the oily residue dissolved in water, and the solution washed with chloroform. The aqueous solution (containing **32**) was made basic (pH 10) with M sodium hydroxide, whereupon an oil separated. This was extracted with ethyl acetate, and the extract dried, and evaporated. The solid residue was filtered with ether, to give pure **34** (1.2 g, 40%); m.p. 171–174°, $[\alpha]_D^{20}$ 0°; R_F 0.5 (*F*); ^{1}H-n.m.r. data (*a* + *c*): δ 8.70 and 8.10 (d,d, tosyl), 3.95 (m, H-2,5), 3.72 and 3.50 (d,d, H-3,4), 3.20 (d, H-6), 2.28 (s, tosyl-Me), and 1.22 (d, H-1).

Anal. Calc. for $C_{13}H_{19}NO_5S$: C, 51.81; H, 6.35; N, 4.65; S, 10.64. Found: C, 51.68; H, 6.50; N, 4.84; S, 10.52.

*2,5:3,4-Dianhydro-1,6-dideoxy-6-(dimethylamino)-*D*-galactitol* (**36**). — A solution of amine **33** (2.2 g) in aqueous formaldehyde (36%; 8 mL) and formic acid (90%; 12 mL) was heated on a steam bath for 1 h. The solution was evaporated, and the residue was filtered (charcoal) with the aid of hydrochloric acid (15 mL), to give, after evaporation, crude **35** as a syrup (2.4 g, 98%); R_F 0.4 (ethanol). To a solution of this syrup in methanol (30 mL) was added 4M methanolic sodium methoxide (5 mL). The solution was made neutral with solid carbon dioxide after 45 min, and then evaporated. The residue was filtered with ether, the filtrate evaporated, and the residue purified by column chromatography (*A*). The fractions having R_F 0.2 gave, on evaporation, pure epoxide **36** as a syrup (1 g, 77%); $[\alpha]_D^{20}$ −9.3°; ^{1}H-n.m.r. data (*a*): δ 3.95 (m, H-2,5), 3.63 and 3.50 (d,d, H-3,4), 2.55 (d, H-6), 2.30 (s, NMe_2), and 1.26 (d, H-1).

Anal. Calc. for $C_8H_{15}NO_2$: N, 8.91. Found: N, 8.47.

*2,5-Anhydro-6-azido-1,6-dideoxy-4-*O-p-*nitrobenzoyl-3-*O-p-*tolylsulfonyl-*D*-glucitol* (**37**). — To a solution of **31** (10.6 g) in pyridine (40 mL) was added tosyl chloride (10 g). The reaction was complete within 2 days. The mixture was poured into water, and the precipitate was filtered off and washed with water to yield crude tosylate **37** (12 g, 77%); m.p. 121–128°, pure enough for further experiments. Recrystallization from methanol–acetone gave pure **37**; m.p. 145–147°, $[\alpha]_D^{20}$ +15°; R_F 0.5 (*F*); ^{1}H-n.m.r. data (*a*): δ 8.32 and 8.12 (d,d, aromatic), 7.82 and 7.28 (d,d, tosyl), 5.28 (d, H-4), 5.03 (d, H-3), 4.30 (m, H-2), 4.00 (m, H-5), 3.55 (m, H-6), 2.38 (s, tosyl-Me), and 1.32 (d, H-1).

Anal. Calc. for $C_{20}H_{20}N_4O_8S$: C, 50.41; H, 4.23; N, 11.76; S, 6.73. Found: C, 50.32; H, 4.25; N, 11.65; S, 6.50.

*2,5:3,4-Dianhydro-6-azido-1,6-dideoxy-*D*-allitol* (**38**). — To a stirred slurry of crude **37** (24 g) in dry chloroform (40 mL) and dry methanol (20 mL) was added 4M methanolic sodium methoxide (14 mL) at room temperature. A clear solution was obtained, from which sodium tosylate started to separate. The slurry was diluted with chloroform after 10 min, washed with water, dried, and evaporated.

The semisolid residue was filtered with the aid of ether–light petroleum, to give crystalline methyl *p*-nitrobenzoate. The filtrate was evaporated, and the residue purified by column chromatography (*F*). The fractions having R_F 0.4 gave, on evaporation, pure epoxide **38** as a syrup (4.4 g, 56%); $[\alpha]_D^{20}$ +36°; ^{1}H-n.m.r. data (*a*): δ 4.20 (m, H-2,5), 3.66 and 3.56 (d,d, H-3,4), 3.33 (m, H-6), and 1.23 (d, H-1).

Anal. Calc. for $C_6H_9N_3O_2$: N, 27.08. Found: N, 26.85.

2,5:3,4-Dianhydro-1,6-dideoxy-6-(dimethylamino)-D-*allitol* (**40**). — A mixture (2.8 g) of azides **41** and **44** was hydrogenated as described for **33**. The reduction was complete within 10 h. Evaporation of the filtered suspension gave a syrupy mixture of amines **42** and **45** (R_F 0.8, *A*). A solution of this mixture in aqueous formaldehyde (36%, 8 mL) and aqueous formic acid (90%, 12 mL) was boiled for 7 h, and evaporated, the residue filtered (charcoal) with the aid of M hydrochloric acid, and the filtrate evaporated. Then ethanol was added to and evaporated from the residue, and this procedure was repeated twice, to give a mixture of the dimethylamino derivatives **43** and **46** as a yellow syrup (R_F 0.6, *A*). To a solution of this syrup in chloroform (20 mL) and methanol (10 mL) was added 4M methanolic sodium methoxide (12 mL). The mixture was boiled for 4 h, cooled, made neutral with solid carbon dioxide, and the solution evaporated; the residue was filtered with ether to give, after evaporation, epoxide **40** as a pale yellow liquid (1.9 g, 83%); $[\alpha]_D^{20}$ −10°; R_F 0.2 (*A*); ^{1}H-n.m.r. data (*a*): δ 4.15 (m, H-2,5), 3.72 and 3.53 (d,d, H-3,4), 2.30 (m, H-6), 2.27 (s, N-Me_2), and 1.22 (d, H-1).

Anal. Calc. for $C_8H_{15}NO_2$: N, 8.91. Found: N, 8.73.

2,5-Anhydro-6-azido-3-chloro-1,3,6-trideoxy-D-*glucitol* (**41**) *and 2,5-anhydro-6-azido-4-chloro-1,4,6-trideoxy*-D-*gulitol* (**44**). — Epoxide **38** (3.1 g) was dissolved in 3.6M methanolic hydrogen chloride (10 mL). After 1 h at room temperature, the solution was made neutral with solid sodium hydrogencarbonate, the salts were filtered off, and the filtrate was evaporated. The residue was partitioned between chloroform and water, and the organic solution was dried, and evaporated, to give an ~1:1 mixture of syrupy **41** + **44** (3.50 g, 91.5%); $[\alpha]_D^{20}$ +42°; R_F 0.3 (*F*); ^{1}H-n.m.r. data (*a*): δ 4.4–3.7 (m, H-2,3,4,5), 3.45 (m, H-6), 2.90 (s, OH), and 1.40 and 1.35 (d,d, H-1).

Anal. Calc. for $C_6H_{10}ClN_3O_2$: Cl, 18.50; N, 21.93. Found: Cl, 18.52; N, 21.67.

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