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SYNTHESIS OF THE 3- AND 4-METHYL, 3,4-DIMETHYL, AND 3,4,6-TRIMETHYL ETHERS OF METHYL 2-ACETAMIDO-2-DEOXY-α-D-MANNOPYRANOSIDE*†

NASIR-UD-DIN AND ROGER W. JEANLOZ**

Laboratory for Carbohydrate Research, Departments of Biological Chemistry and Medicine, Harvard Medical School and Massachusetts General Hospital, Boston, Massachusetts 02114 (U. S. A.)

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ABSTRACT

The methyl ethers of 2-amino-2-deoxy-D-mannose are reference compounds in studies, by the methylation procedure, of the chemical structure of polysaccharides containing 2-amino-2-deoxy-D-mannose and 2-amino-2-deoxy-D-mannuronic acid residues. Methylation of methyl 2-acetamido-2-deoxy-α-D-mannopyranoside (**1**) gave the 3,4,6-trimethyl ether. Methylation of the 6-trityl ether of **1**, followed by detritylation, gave the 3,4-dimethyl ether of **1**. Methylation of the 4,6-*O*-benzylidene derivative (**6**) of **1**, followed by removal of the benzylidene group, gave the 3-methyl ether of **1**. Benzoylation of **6**, followed by removal of the benzylidene group and monobenzoylation, gave the 3,6-dibenzoate of **1**, which was methylated, and the product saponified, to give the 4-methyl ether of **1**; the latter compound was also obtained by a similar route *via* the 3-*O*-acetyl-6-*O*-benzoyl derivative.

INTRODUCTION

The polysaccharide linked to the peptidoglycan of the cell wall of *Micrococcus lysodeikticus* contains residues of both D-glucose and 2-amino-2-deoxy-D-mannuronic acid[1]. The chemical structure of this polysaccharide was established by the methylation procedure, the polysaccharide being methylated, the ether reduced, and the product methanolyzed[2]. In order to identify the resulting fragments, the 3-methyl, 4-methyl, and 3,4-dimethyl ethers of methyl 2-acetamido-2-deoxy-α-D-mannopyranoside were synthesized, because the methanolysis gives a mixture of the anomeric forms in which the α-D-pyranoside form preponderates. In addition, the synthesis

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**To whom inquiries should be sent.

of the 3,4,6-trimethyl ether is reported. These methyl ethers are also of interest for the elucidation of the structure of polysaccharides containing 2-amino-2-deoxy-D-mannose residues; such carbohydrates have been isolated from Salmonella groups J and T, *Escherichia coli* O_{31}, Arizona 15 (Ref. 3), and from a capsular polysaccharide[4] of Pneumococcus Type IV.

RESULTS AND DISCUSSION

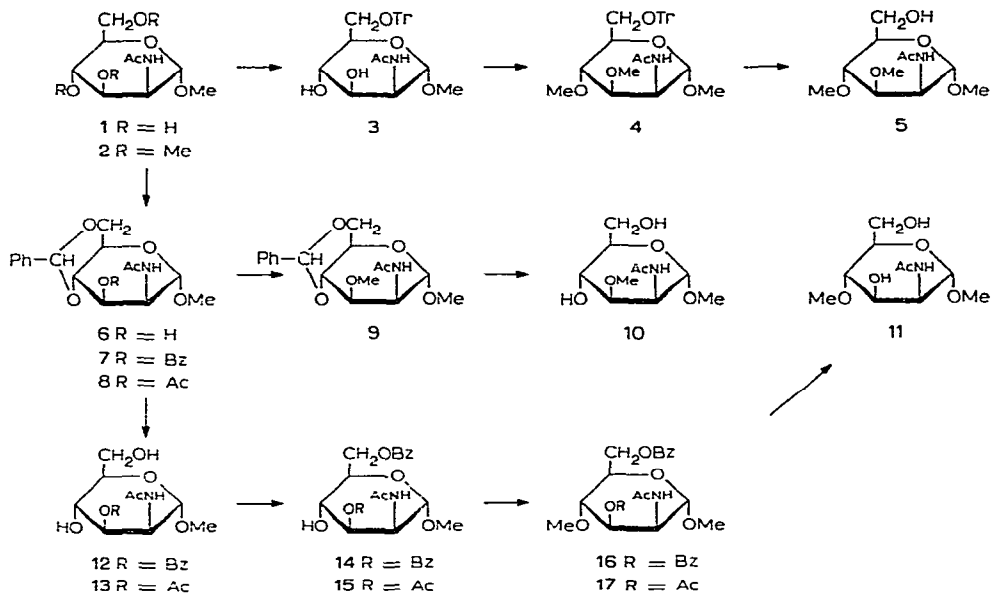
(*a*) Methyl 2-acetamido-2-deoxy-α-D-mannopyranoside (**1**) was obtained in 9% yield by glycosidation of 2-acetamido-2-deoxy-D-mannose, followed by separation of the α- and β-D furanosides and pyranosides by means of Dowex-1 resin and preparative paper-chromatography[5]; this method, the second step of which required 55 sheets of Whatman No. 1 paper for the preparation of 218 mg of **1**, is not practical for the preparation of larger amounts of starting material. (*b*) The separation of the glycosides by using only a Dowex-1 column[6] probably gave a mixture of the two furanosides and two pyranosides. (*c*) Preparation of the 3,4,6-tri-*O*-acetyl derivative of **1** *via* the 2-methyl-4,5-(3,4,6-tri-*O*-acetyl-2-deoxy-D-mannopyrano)-2-oxazoline gave a very low yield[7]. (*d*) Application of the improved synthesis of the oxazoline according to Khorlin *et al.*[8] did not, in our hands, give the high yields (82%) reported. (*e*) However, removal of the benzylidene group of methyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-α-D-mannopyranoside (**6**), which had been obtained from methyl 4,6-*O*-benzylidene-α-D-glucopyranoside by the methods of Foster *et al.*[9], Buss *et al.*[10], and Sinaÿ *et al.*[11], gave **1** in syrupy form and 89% yield. This compound showed an optical rotation identical with that of the compound previously described[5].

In order to avoid *N*-methylation, the classical method of Purdie and Irvine[12] was applied to **1**, and the crystalline 3,4,6-trimethyl ether (**2**) was obtained in 70% yield.

Treatment of **1** with chlorotriphenylmethane gave a crystalline 6-trityl ether (**3**), which was methylated by the Purdie reagents to give the crystalline 3,4-dimethyl ether (**4**); removal of the trityl group gave the crystalline 3,4-dimethyl ether (**5**) of **1** in an overall yield of 65% (calculated on **1**).

Methylation of the benzylidene derivative **6**, followed by removal of the benzylidene group from the crystalline intermediate **9**, gave the amorphous 3-methyl ether (**10**) of **1** in an overall yield of 62%.

Synthesis of the 4-methyl ether (**11**) of **1** was achieved *via* two different routes. In the first, the 3-hydroxyl group of the benzylidene derivative **6** was protected with a benzoyl group, to give the crystalline monobenzoate **7**. Removal of the benzylidene group thereof was followed by monobenzoylation at O-6 of the crystalline intermediate **12**, to give the crystalline 3,6-dibenzoate (**14**). Methylation of **14** afforded the crystalline 4-methyl ether **11** in an overall yield of 27% (based on **6**). A similar sequence of reactions that used an acetyl group at O-3 for protection, and proceeded *via* the known[11] crystalline 3-*O*-acetyl-4,6-*O*-benzylidene (**8**), amorphous 3-*O*-acetyl (**13**), crystalline 3-*O*-acetyl-6-*O*-benzoyl (**15**), and syrupy 3-*O*-acetyl-6-*O*-



benzoyl-4-*O*-methyl (**17**) derivatives, gave the 4-methyl ether **11** in an overall yield of 25% (based on **6**); methylation of **15** was performed in the presence of boron trifluoride etherate by the method of Gros *et al.*[13], which has been shown not to cause migration of the *O*-acetyl groups. The location of the 4-*O*-methyl group was ascertained by the preparation of a 6-trityl ether (which was not further characterized).

EXPERIMENTAL

General. — Melting points were determined with a Mettler FP-2 apparatus, and correspond to "corrected melting points". Optical rotations were measured, in semimicrotubes, with a Perkin–Elmer Model 141 polarimeter. I.r. spectra were recorded, for potassium bromide discs, with a Perkin–Elmer Model 237 spectrophotometer. The chloroform used was analytical-reagent grade, and contained 0.75% of ethanol. Column chromatography was performed on Silica Gel Merck (70–325 mesh; E. Merck, Darmstadt, Germany), used without pretreatment. The ratio of weight of substance to weight of adsorbent was 1:70 to 1:100. The volume of the fractions eluted was 4–5 ml per gram of the substance to be chromatographed. T.l.c. was performed on precoated silica gel plates (without fluorescence indicator; layer thickness 0.25 mm; E. Merck, Darmstadt, Germany); all compounds showed only one spot. The R_{TMG} values refer to the mobilities on plates of silica gel, relative to that of methyl 2-acetamido-2-deoxy-3,4,6-tri-*O*-methyl-α-D-glucopyranoside. Evaporations were conducted *in vacuo*, with the bath temperature kept below 40°. Microanalyses were performed by Dr. W. Manser, Zürich, Switzerland.

Methyl 2-acetamido-2-deoxy-α-D-mannopyranoside (**1**). — Compound **6** (80 mg) was heated with 60% acetic acid (3.5 ml) for 1 h on a water bath at 80°.

The solution was cooled and evaporated, and a mixture of methanol and toluene was repeatedly added to and distilled from the residue. The residue was chromatographed on silica gel in 7:3 chloroform–ethanol, and elution gave 52 mg (89%) of a syrup, $[\alpha]_D^{20}$ +50° (*c* 0.9, water) {lit.[5] : $[\alpha]_D^{24}$ +50° (*c* 1.6, water)}, $[\alpha]_D^{20}$ +47° (*c* 0.8, methanol); i.r. data : ν_{max}^{KBr} 3450 (broad; OH), 1650 (Amide I), and 1548 cm^{-1} (Amide II); t.l.c. in 7:3 chloroform–ethanol: R_F 0.4.

Anal. Calc. for $C_9H_{17}NO_6$: C, 45.95; H, 7.28; N, 5.95. Found: C, 45.83; H, 7.26; N, 5.93.

*Methyl 2-acetamido-2-deoxy-3,4,6-tri-*O*-methyl-α-*D*-mannopyranoside* (**2**). — A solution of **1** (45 mg) in dry acetone (1 ml) was treated with methyl iodide (3 ml) and silver oxide (200 mg). The mixture was boiled under reflux for 12 h. After a new addition of silver oxide (100 mg), the mixture was boiled under reflux for 6 h, and then cooled to room temperature. Examination of the products by t.l.c. in 9:1 chloroform–ethanol showed the total conversion of the starting material. The mixture was filtered, the residue was washed repeatedly with warm chloroform, and the combined filtrates were evaporated *in vacuo*. The residue was chromatographed on silica gel with 19:1 chloroform–ethanol, to give a product that crystallized from ether in plates (37 mg, 70%), m.p. 98–99°, $[\alpha]_D^{20}$ +39° (*c* 0.33, chloroform); i.r. data : ν_{max}^{KBr} 3250 (NH), 1630 (Amide I), and 1550 cm^{-1} (Amide II); t.l.c. in 19:1 chloroform–ethanol : R_F 0.5; R_{TMG} 1.0. The product contained one molecule of water per molecule.

Anal. Calc. for $C_{12}H_{23}NO_6 \cdot H_2O$: C, 48.80; H, 8.53; N, 4.74. Found: C, 49.00; H, 8.25; N, 4.88.

After being melted *in vacuo* and cooled, the compound showed the following analytical values.

Anal. Calc. for $C_{12}H_{23}NO_6$: C, 51.97; H, 8.36; N, 5.05; O, 34.62; OMe, 44.72. Found: C, 51.93; H, 8.34; N, 4.89; O, 34.82; OMe, 44.26.

*Methyl 2-acetamido-2-deoxy-6-*O*-trityl-α-*D*-mannopyranoside* (**3**). — A solution of **1** (65 mg) in dry pyridine (3 ml) was treated with chlorotriphenylmethane (88 mg) for 46 h at room temperature, and then the mixture was poured onto crushed ice. The precipitate was dissolved in chloroform (15 ml), and the solution was washed with cold water (4 × 4 ml), dried (sodium sulfate), and evaporated; repeated addition and distillation of toluene gave a residue that, on examination by t.l.c. in 4:1 chloroform–ethanol, showed two components, one corresponding to triphenylmethanol. The mixture was chromatographed on silica gel, with 9:1 chloroform–ethanol, to give a compound that crystallized from ethanol–ether as refringent plates (117 mg, 89%), m.p. 122–123°, $[\alpha]_D^{20}$ +6° (*c* 0.61, methanol); i.r. data : ν_{max}^{KBr} 3460 (OH), 3300 (NH), 1650 (Amide I), 1560 (Amide II), 1490 (Ar), 1450 (Ar), and 670 cm^{-1} (Ph); t.l.c. in 9:1 chloroform–ethanol: R_F 0.5.

Anal. Calc. for $C_{28}H_{31}NO_6$: C, 70.42; H, 6.54; N, 2.93; O, 20.10. Found: C, 70.41; H, 6.60; N, 2.82; O, 20.36.

*Methyl 2-acetamido-2-deoxy-3,4-di-*O*-methyl-6-*O*-trityl-α-*D*-mannopyranoside* (**4**). — A solution of **3** (115 mg) in methyl iodide (3 ml) was boiled under reflux with silver oxide (250 mg) for 12 h, and then for 6 h after a further addition of silver

oxide (100 mg). Examination of the mixture by t.l.c. in 19:1 chloroform–ethanol showed total conversion of the starting material. After filtration, the solids were washed with warm chloroform, and the combined filtrates were dried (sodium sulfate) and evaporated. The residue was chromatographed on silica gel, with 19:1 chloroform–ethanol, to give 99 mg (81%) of a compound that crystallized from ethanol as plates, m.p. 117–119°, $[\alpha]_D^{20}$ +7° (*c* 0.51, methanol); i.r. data : ν_{max}^{KBr} 3425–3430 (NH), 1675 (Amide I), 1515 (Amide II), 1600, 1490, and 1450 cm^{-1} (Ar); t.l.c. in 9:1 chloroform–ethanol: R_F 0.6.

Anal. Calc. for $C_{30}H_{35}NO_6$: C, 71.27; H, 6.98; N, 2.77; OMe, 18.41. Found: C, 71.17; H, 6.93; N, 2.73; OMe, 18.75.

*Methyl 2-acetamido-2-deoxy-3,4-di-*O*-methyl-α-*D*-mannopyranoside* (**5**). — A solution of **4** (90 mg) in glacial acetic acid (3 ml) was heated on a water bath (80°); then, water (2 ml) was added dropwise, heating was continued for 45 min, the mixture was cooled to room temperature, and water (8 ml) was added. The precipitated triphenylmethanol was filtered off, and the filtrate was diluted to 100 ml with water, and freeze-dried to give a syrup. Chromatography of this syrup on silica gel, with 19:1 chloroform–ethanol, gave 42 mg (90%) of material that crystallized from methanol–ether as needles, m.p. 175–176°, $[\alpha]_D^{20}$ +52° (*c* 0.44, ethanol); i.r. data : ν_{max}^{KBr} 3545 (OH), 3250 (NH), 1635 (Amide I), and 1555 cm^{-1} (Amide II); t.l.c. in 19:1 chloroform–ethanol: R_F 0.2; R_{TMG} 0.7.

Anal. Calc. for $C_{11}H_{21}NO_6$: C, 50.18; H, 8.04; N, 5.32; OMe, 35.36. Found: C, 50.11; H, 8.01; N, 5.26; OMe, 34.97.

*Methyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-3-*O*-methyl-α-*D*-mannopyranoside* (**9**). — A mixture of compound[11] **6** (100 mg), methyl iodide (8.5 ml), and silver oxide (300 mg) in dry tetrahydrofuran (1.5 ml) was boiled under reflux for 8 h, and heating was continued for 12 h after a further addition of silver oxide (150 mg). After filtration, the residue was successively washed with three 50-ml portions of warm chloroform and two 5-ml portions of methanol, and the combined filtrates were evaporated. The residue was chromatographed on silica gel with 9:1 chloroform–ethanol. A pure fraction was obtained that crystallized from methanol to give 84 mg (80%) as plates, m.p. 81–84°, $[\alpha]_D^{20}$ +15° (*c* 0.54, chloroform); i.r. data : ν_{max}^{KBr} 3300 (NH), 1650 (Amide I), 1540 (Amide II), 1450 (Ar), and 640 cm^{-1} (Ph); t.l.c. in 19:1 chloroform–ethanol: R_F 0.5.

Anal. Calc. for $C_{17}H_{23}NO_6$: C, 60.52; H, 6.87; N, 4.15; O, 28.45; OMe, 18.40. Found: C, 60.38; H, 6.95; N, 4.00; O, 28.57; OMe, 18.34.

*Methyl 2-acetamido-2-deoxy-3-*O*-methyl-α-*D*-mannopyranoside* (**10**). — A solution of **9** (80 mg) in 60 % acetic acid (8 ml) was heated for 1 h on a water bath (80°), and evaporated; the residue was dried by repeated addition and distillation of toluene, dissolved in water (100 ml), and freeze-dried to give a syrup. The syrup was chromatographed on silica gel with 4:1 chloroform–ethanol to give 46 mg (78%) of amorphous **10**, $[\alpha]_D^{20}$ +20° (*c* 0.69, methanol); i.r. data : ν_{max}^{film} 3500 (broad, OH), 1650 (Amide I), and 1545 cm^{-1} (Amide II); t.l.c. in 4:1 chloroform–ethanol: R_F 0.5; R_{TMG} 0.4.

Anal. Calc. for $C_{10}H_{19}NO_6$: C, 48.19; H, 7.68; N, 5.62; OMe, 24.50. Found: C, 48.12; H, 7.60; N, 5.66; OMe, 24.46.

*Methyl 2-acetamido-3-*O*-benzoyl-4,6-*O*-benzylidene-2-deoxy-α-*D*-mannopyranoside* (**7**). — A solution of **6** (250 mg) in dry pyridine (4 ml) was cooled to −60°, treated with benzoyl chloride (89 µl) for 4 h at −20° and 12 h at −5°, and then diluted with chloroform (10 ml). The clear solution was successively washed with ice-cold, saturated solutions of sodium hydrogen sulfate and sodium hydrogen carbonate, and with ice-cold water, dried (sodium sulfate), and evaporated to give a syrup which was chromatographed on silica gel with 19:1 chloroform–ethanol. The product (220 mg, 75%) crystallized from chloroform–ethanol as small needles, m.p. 236–237°, $[\alpha]_D^{20}$ −22° (*c* 0.59, methanol); i.r. data: ν_{max}^{KBr} 3405 (NH), 1700 (ester), 1670 (Amide I), 1550 (Amide II), 715, and 690 cm^{-1} (Ph); t.l.c. in 19:1 chloroform–ethanol: R_F 0.6.

Anal. Calc. for $C_{23}H_{25}NO_7$: C, 64.63; H, 5.90; N, 3.28; O, 26.20. Found: C, 64.40; H, 5.86; N, 3.20; O, 26.48.

*Methyl 2-acetamido-3-*O*-benzoyl-2-deoxy-α-*D*-mannopyranoside* (**12**). — A solution of **7** (225 mg) in glacial acetic acid (4 ml) was heated on a water bath (80°); the hot solution was diluted with water (2 ml), and heating was continued for 1 h. The solution was cooled and evaporated, the residue was dissolved in water (150 ml), and the solution was freeze-dried to give a syrup (154 mg). Chromatography of this syrup on silica gel in 7:3 chloroform–ethanol gave 142 mg (80%) of material that crystallized from ethanol–chloroform to give plates containing one molecule of chloroform per molecule, which was not removed by drying the melted product in high vacuum; m.p. 115–116°, $[\alpha]_D^{20}$ +35° (*c* 0.75, methanol); i.r. data: ν_{max}^{KBr} 3330 (OH), 3200 (NH), 1710 (ester), 1650 (Amide I), 1550 (Amide II), 775 (C–Cl), and 710 cm^{-1} (Ph); t.l.c. in 4:1 chloroform–ethanol: R_F 0.4.

Anal. Calc. for $C_{16}H_{21}NO_7 \cdot CHCl_3$: C, 44.51; H, 4.83; Cl, 23.18; N, 3.05; O, 24.41. Found: C, 45.06; H, 4.87; Cl, 23.08; N, 3.21; O, 24.81.

Crystallization of **12** from methanol–ether gave prisms that contained 0.5 molecule of ether per molecule, m.p. 107–109°.

Anal. Calc. for $C_{16}H_{21}NO_7 \cdot 0.5\ C_2H_5OC_2H_5$: C, 57.43; H, 6.96; N, 3.72. Found: C, 57.56; H, 7.08; N, 3.84.

*Methyl 2-acetamido-3,6-di-*O*-benzoyl-2-deoxy-α-*D*-mannopyranoside* (**14**). — A solution of **12** (90 mg) in dry pyridine (3 ml) was cooled to −70° and benzoyl chloride (33 µl) was slowly added. The mixture was kept for 2 h at −20° and 12 h at −5°, and then processed as described for compound **7**. The product was chromatographed on silica gel, with 9:1 chloroform–ethanol, and a syrupy material (82 mg, 70%) was obtained that crystallized from chloroform–ether; m.p. 208–209°, $[\alpha]_D^{20}$ +89° (*c* 0.32, chloroform); i.r. data: ν_{max}^{KBr} 3530 (OH), 3280 (NH), 1710 and 1690 (ester), 1660 (Amide I), 1600 (Ar), and 1530 cm^{-1} (Amide II); t.l.c. in 9:1 chloroform–ethanol: R_F 0.7.

Anal. Calc. for $C_{23}H_{25}NO_8$: C, 62.30; H, 5.68; N, 3.16; O, 28.86. Found: C, 62.04; H, 5.63; N, 3.23; O, 29.14.

Methyl 2-acetamido-3,6-di-O-benzoyl-2-deoxy-4-O-methyl-α-D-mannopyranoside (**16**). — Compound **14** (45 mg) in dry acetone (1 ml) was treated with methyl iodide (2 ml) and silver oxide (150 mg) for 32 h at room temperature, with vigorous stirring of the reaction mixture. A further 100 mg of silver oxide was added, and stirring was continued for 12 h. The solids were filtered off, and washed with warm chloroform, and the combined filtrate and washings were evaporated. The residue was dissolved in methyl iodide (3 ml) and re-treated with silver oxide (200 mg) for 32 h. After processing the mixture as described for **2**, the residue was chromatographed on silica gel. Elution with 29:1 chloroform–ethanol gave 36 mg (78%) of material that, on crystallization from ether, gave stout needles, m.p. 151–152°, $[\alpha]_D^{20}$ +59° (*c* 0.37, chloroform); i.r. data: ν_{max}^{KBr} 3200 (NH), 1720 (ester), 1655 (Amide I), 1585 (Ar), and 1550 cm^{-1} (Amide II); t.l.c. in 19:1 chloroform–ethanol: R_F 0.8.

Anal. Calc. for $C_{24}H_{27}NO_8$: C, 63.01; H, 5.95; N, 3.06; OMe, 13.57. Found: C, 63.00; H, 5.86; N, 3.07; OMe, 13.43.

Methyl 2-acetamido-2-deoxy-4-O-methyl-α-D-mannopyranoside (**11**). — *A. From* **16**. A solution of **16** (28 mg) in dry methanol (2 ml) was treated with 0.1M methanolic sodium methoxide (0.1 ml) for 18 h at 4°, and then diluted with methanol (2 ml), and de-ionized with Rexyn 300 (H^+, OH^-) ion-exchange resin (1 ml), and evaporated. The residue was chromatographed on silica gel with 4:1 chloroform–ethanol to give 12.6 mg (83%) of material that crystallized from methanol–ether as plates, m.p. 121–123°, $[\alpha]_D^{20}$ +43° (*c* 0.53, methanol); i.r. data: ν_{max}^{KBr} 3370 (OH), 3260 (NH), 1650 (Amide I), 1550 (Amide II), and 1130–1090 cm^{-1} (CH–O–CH_2–); t.l.c. in 4:1 chloroform–ethanol: R_F 0.5; R_{TMG} 0.3.

Anal. Calc. for $C_{10}H_{19}NO_6$: C, 48.19; H, 7.68; N, 5.62. Found: C, 47.97; H, 7.54; N, 5.74.

B. From **17**. A solution of **17** (26 mg) in methanol (2 ml) was treated with 0.1M methanolic sodium methoxide (0.1 ml) for 2 h at 0° and for 8 h at room temperature. The solution was treated with Rexyn 300 (H^+,OH^-) ion-exchange resin (1 ml) and evaporated. The residue crystallized, as plates, from methanol–ether (12.9 mg, 80%), m.p. 120–122°, $[\alpha]_D^{20}$ +43° (*c* 0.42, methanol); t.l.c. in 4:1 chloroform–ethanol: R_{TMG} 0.3, a value identical with that for the product obtained from **16**.

A solution of **11** (1.5 mg) in dry pyridine (1 ml) was treated with chlorotriphenylmethane (1.2 mg) for 48 h at room temperature. The solution was evaporated, and the residue was fractionated by t.l.c. in 9:1 chloroform–ethanol to give triphenylmethanol and the trityl ether of **11**. This compound was treated with 60% acetic acid (1 ml) for 1 h at 80°; t.l.c. in 9:1 chloroform–ethanol then indicated the presence of **11** and triphenylmethanol.

Methyl 2-acetamido-3-O-acetyl-4,6-O-benzylidene-2-deoxy-α-D-mannopyranoside (**8**). — Acetic anhydride (2 ml) was added to a solution of **6** (150 mg) in dry pyridine (2 ml), cooled to 0°, and the solution was kept for 30 h at room temperature, diludet with chloroform (10 ml), and evaporated; repeated addition and distillation of toluene gave a crystalline residue. Recrystallization from methanol–ether gave 145 mg (85%) of needles, m.p. 210–212°, $[\alpha]_D^{20}$ +34° (*c* 0.62, methanol); $[\alpha]_D^{20}$ +31° (*c* 0.46,

chloroform); i.r. data: ν_{max}^{KBr} 3405 (NH), 1700 (ester), 1670 (Amide I), and 1530 cm^{-1} (Amide II); t.l.c. in 19:1 chloroform–ethanol: R_F 0.55. Compound **8** has been reported[11] to exist in a crystalline form containing 0.5 molecule of water per molecule, m.p. 205–208°, $[\alpha]_D^{25}$ −11° (*c* 1.0, pyridine); $[\alpha]_D^{25}$ +32° (*c* 0.6, chloroform).

Anal. Calc. for $C_{18}H_{23}NO_7$: C, 59.17; H, 6.34; N, 3.83; O, 30.65. Found: C, 59.13; H, 6.37; N, 3.78; O, 30.75.

*Methyl 2-acetamido-3-*O*-acetyl-2-deoxy-α-*D*-mannopyranoside* (**13**). — Compound **8** (130 mg) was heated with 60% acetic acid (5 ml) for 1 h on a water bath (80°). The solution was cooled and concentrated, and toluene was repeatedly added and distilled off. The residue was chromatographed on silica gel, and elution with 7:3 chloroform–ethanol gave 89 mg (90%) of amorphous **13**; $[\alpha]_D^{20}$ +42° (*c* 1.72, methanol); i.r. data: ν_{max}^{film} 3540 (OH), 3290 (NH), 1750 (OAc), 1665 (Amide I), and 1555 cm^{-1} (Amide II); t.l.c. in 4:1 chloroform–ethanol: R_F 0.3.

Anal. Calc. for $C_{11}H_{19}NO_7$: C, 47.65; H, 6.91; N, 5.05; O, 40.39. Found: C, 47.64; H, 6.91; N, 4.92; O, 40.56.

*Methyl 2-acetamido-3-*O*-acetyl-6-*O*-benzoyl-2-deoxy-α-*D*-mannopyranoside* (**15**). — A solution of **13** (80 mg) in dry pyridine (4 ml) was cooled to −60°. Benzoyl chloride (34 μl) was slowly added, and the mixture was kept for 1 h at −20° and for 12 h at −5°, and then processed as described for **7**. Chromatography of the resulting syrup (95 mg) on silica gel with 19:1 chloroform–ethanol gave **15**, which crystallized from ether–benzene as needles (65 mg, 60%), m.p. 96–100°, $[\alpha]_D^{20}$ +44° (*c* 0.73, methanol); i.r. data: ν_{max}^{KBr} 3500 (OH), 3300 (NH), 1720 (ester), 1695 (Amide I), and 1560 cm^{-1} (Amide II); t.l.c. in 9:1 chloroform–ethanol: R_F 0.5.

Anal. Calc. for $C_{18}H_{23}NO_8$: C, 56.69; H, 6.08; N, 3.67; O, 33.56. Found: C, 56.58; H, 6.04; N, 3.60; O, 33.56.

*Methyl 2-acetamido-3-*O*-acetyl-6-*O*-benzoyl-2-deoxy-4-*O*-methyl-α-*D*-mannopyranoside* (**17**). — A solution of **15** (46 mg) in anhydrous ether (4 ml) was cooled to −10°, boron trifluoride etherate (0.05 ml of a 3.3% solution in ether) was added, and the mixture was treated with diazomethane in ether until the yellow color of diazomethane persisted. T.l.c. in 19:1 benzene–methanol showed incomplete conversion of **15**. The solution was filtered through a sintered funnel (to remove polymeric material), the filtrate was evaporated, and the residue was dried under high vacuum. The methylation was repeated, and the resulting syrup was chromatographed on silica gel with 14:1 benzene–chloroform, to give amorphous **17** (33 mg, 69%), $[\alpha]_D^{20}$ +54° (*c* 0.5, methanol); i.r. data: ν_{max}^{KBr} 3300 (NH), 1775 and 1730 (ester), 1650 (Amide I) and 1540 cm^{-1} (Amide II); t.l.c. in 19:1 chloroform–ethanol: R_F 0.6.

Anal. Calc. for $C_{19}H_{25}NO_8$: C, 57.71; H, 6.37; N, 3.54; OMe, 15.69. Found: C, 57.64; H, 6.44; N, 3.57; OMe, 15.40.

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