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DERIVATIVES OF 6-DEOXY-L-TALOSE AND THE SYNTHESIS OF 6-DEOXY-2-*O*-(α-L-RHAMNOPYRANOSYL)-L-TALOSE

GERALD O. ASPINALL
Department of Chemistry, York University, Downsview, Toronto, Ontario M3J 1P3 (Canada)

AND KEN'ICHI TAKEO
Department of Agricultural Chemistry, Kyoto Prefectural University, Shimogamo, Kyoto 606 (Japan)
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ABSTRACT

Benzyl 6-deoxy-α-L-talopyranoside (**10**) has been synthesized and provides, after hydrogenolysis, an improved preparation of 6-deoxy-L-talose. Several partially substituted derivatives of the glycoside **10** have been prepared, including benzyl 6-deoxy-3,4-*O*-isopropylidene-α-L-talopyranoside and benzyl 3,4-di-*O*-benzyl-6-deoxy-α-L-talopyranoside. Both of these have served as aglycons for condensation with 2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl bromide to furnish, after removal of protecting groups, 6-deoxy-2-*O*-(α-L-rhamnopyranosyl)-L-talose (**36**). This disaccharide occurs as the inner unit of oligosaccharide chains in the polar glycopeptidolipid antigens in the *Mycobacterium avium–M. intracellulare–M. scrofulaceum* serocomplex. A derivative of disaccharide **36**, benzyl 3,4-di-*O*-benzyl-6-deoxy-2-*O*-(2,4-di-*O*-benzoyl-α-L-rhamnopyranosyl)-α-L-talopyranoside, has been synthesized to serve as the common aglycon for the attachment of serovar-specific, external sugar residues.

INTRODUCTION

The distinctive features of the "C-mycoside" glycopeptidolipid-typing, surface antigens from the *Mycobacterium avium–M. intracellulare–M. scrofulaceum* (MAIS) serocomplex are short, partially acetylated oligosaccharide chains *O*-glycosylically linked to D-allothreonine residues in a short, apparently invariant lipopeptide[1]. That these oligosaccharides, in turn, contain a common interior disaccharide component of 3-*O*-substituted α-L-rhamnopyranosyl-(1→2)-6-deoxy-L-talose has been established in detailed structural studies on the oligosaccharides from serovars 8, 9, and 25 (ref. 2). The generality of this structural feature is supported in further structural studies on serovars 19 (ref. 3), 2, and 20 (ref. 4), and in compositional studies on several other serovars[1,5]. We now report a synthesis of this disaccharide, 6-deoxy-2-*O*-(α-L-rhamnopyranosyl)-L-talose (**36**), together with a derivative, benzyl 3,4-di-*O*-benzyl-6-deoxy-2-*O*-(2,4-di-*O*-benzoyl-α-L-rham-

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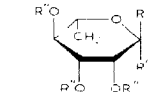
nopyranosyl)-α-L-talopyranoside (**35**), suitably substituted to act as a glycosyl acceptor for the attachment of the serovar-specific outer sugar residues. We also describe the synthesis of a series of partially substituted derivatives of benzyl 6-deoxy-α-L-talopyranoside (**10**) and an improved preparation of 6-deoxy-L-talose (**37**).

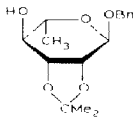
RESULTS AND DISCUSSION

Benzyl α-L-rhamnopyranoside[6] (**5**) was prepared from L-rhamnose (**1**) in an overall yield of 68%, by a sequence involving acetylation (to give 1,2,3,4-tetra-*O*-acetyl-L-rhamnopyranose[7], **2**), treatment of **2** with hydrogen bromide in acetic acid (to give 2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl bromide[8], **3**), condensation of **3** with benzyl alcohol in the presence of mercuric cyanide in dichloromethane (to give benzyl 2,3,4-tri-*O*-acetyl-α-L-rhamnopyranoside[6] **4**), and subsequent *O*-deacetylation. Compound **5** was converted by treatment with 2,2-dimethoxypropane in the presence of *p*-toluenesulfonic acid into the 2,3-isopropylidene acetal[9] **6** in 90% yield. After this preparation had been completed, Lipták *et al.*[10]

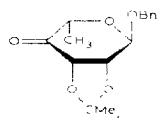


1-5

1 R = H, OH, R'' = H
2 R = H, OAc, R'' = Ac
3 R = Br, R' = H, R'' = Ac
4 R = OBn, R' = H, R'' = Ac
5 R = OBn, R' = R'' = H



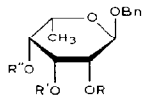
6



7

reported a similar method of acetonation. Oxidation of **6** with ruthenium tetraoxide[11] gave, after chromatography on a column of silica gel, the glycos-4-ulose derivative **7** as a syrup in 76% yield. Compound **7** was stereoselectively reduced with sodium borohydride and the major product, benzyl 6-deoxy-2,3-*O*-isopropylidene-α-L-talopyranoside (**9**), was most conveniently isolated in 78% yield as the crystalline, 4-*O*-acetyl-2,3-*O*-isopropylidene derivative **8**. Subsequently, it was found that the isolation of **7** is not necessary for the preparation of **8**. The product mixture obtained by oxidation of **6** was successively reduced with sodium borohydride and acetylated to give **8** in 81% yield. Alternatively, oxidation of **6** was performed in *N*,*N*-dimethylformamide with dimethyl sulfoxide–phosphorus pentaoxide[12]. In this case, however, compound **7** was slightly contaminated with a marginally faster-moving (t.l.c.) component that could not be removed by column chromatography. Nevertheless, this method was satisfactory for the preparation of **8**. The product mixture obtained by oxidation of **6** was sequentially reduced and acetylated to afford **8** in 72% yield. Removal of the isopropylidene group from **9** with aqueous ace-

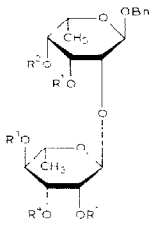
tic acid gave crystalline **10** in 91% yield. Acetylation of **10** gave the 2,3,4-tri-*O*-acetyl derivative **11**. Hydrogenolysis of **10** afforded crystalline 6-deoxy-L-talose[13] (**37**) in 80% yield. The seven-step sequence **5** → **6** → **7** → **9** → **8** → **9** → **10** → **37**, giving **37** in 43–48% yield (based on **5**) without recourse to chromatographic fractionation at any stages, provides the most satisfactory synthesis of **37**, and is clearly superior to earlier analogous synthesis[13] from methyl α-L-rhamnopyranoside or methyl α-L-fucopyranoside.



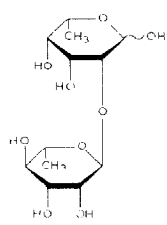
8 – 29

8	R, R' = CMe_2; R'' = Ac	**19**	R = R' = OH, R'' = Bn
9	R, R' = CMe_2; R'' = H	**20**	R = R'' = Bn, R' = H
10	R = R' = R'' = H	**21**	R = R'' = Bn, R' = Me
11	R = R' = R'' = Ac	**22**	R = All, R' = H, R'' = Bn
12	R = H, R', R'' = CMe_2	**23**	R = H, R' = All, R'' = Bn
13	R = All, R', R'' = CMe_2	**24**	R = R'' = Bn, R' = All
14	R = All, R' = R'' = H	**25**	R = All, R' = Bz, R'' = Bn
15	R = All, R' = R'' = Bn	**26**	R = Bz, R' = All, R'' = Bn
16	R = H, R' = R'' = Bn	**27**	R = Bz, R' = H, R'' = Bn
17	R = Me, R' = R'' = Bn	**28**	R = H, R' = Bz, R'' = Bn
18	R, R' = CMe_2; R'' = Bn	**29**	R = R' = Bz, R'' = Bn

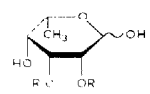
Acetonation of **10** with 2,2-dimethoxypropane in the presence of *p*-toluenesulfonic acid afforded a mixture that was fractionated on a column of silica gel to give the 3,4- (**12**) and 2,3- (**9**) isopropylidene acetals in 76 and 8% yields, respectively. The structure of compound **12** was confirmed by methylation, followed by hydrolysis, reduction, and acetylation to give 6-deoxy-2-*O*-methyl-L-talitol tetraacetate (**42**), whose substitution pattern was clearly shown by its mass spectrum. Compound **12** was alkylated[14] with allyl bromide and the syrupy product **13** deisopropylidenated with aqueous acetic acid to give crystalline benzyl 2-*O*-allyl-6-deoxy-α-L-talopyranoside (**14**). Benzylation[14] of **14** with benzyl bromide, followed by *O*-deallylation of the product **15**, furnished benzyl 3,4-di-*O*-benzyl-6-deoxy-α-L-talopyranoside (**16**), whose substitution pattern was confirmed by methylation to give **17**, which in turn on hydrogenolysis afforded 6-deoxy-2-*O*-methyl-L-talose (**38**). The partially methylated sugar was, as before, characterized by conversion into the corresponding partially methylated alditol acetate **42**. In the foregoing reaction-sequence, *O*-deallylation was achieved equally satisfactorily by isomerization of the allyl to 1-propenyl ether with the Wilkinson catalyst [tris(triphenylphosphine)rhodium chloride] in the presence of 1,4-diazabicyclo[2.2.2]octane[15] followed by mild acid hydrolysis, or in a single step by treatment with palladium-on-



30–35



36



37–39

30 $R^1, R^2 = CMe_2$, $R^3 = R^4 = R^6 = H$
31 $R^1, R^2 = CMe_2$, $R^3 = R^4 = R^6 = Ac$
32 $R^1 = R^2 = R^3 = R^4 = R^6 = H$
33 $R^1 = R^2 = Bn$, $R^3 = R^4 = R^6 = H$
34 $R^1 = R^2 = Bn$, $R^3 = R^4 = R^6 = Ac$
35 $R^1 = R^2 = Bn$, $R^3 = R^6 = Bz$, $R^4 = H$

37 $R = R' = H$
38 $R = Me$, $R' = H$
39 $R = H$, $R' = Me$

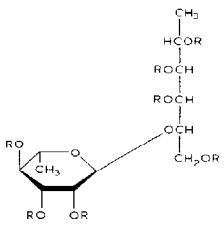
charcoal in acidified solution[16]. Both 3,4-di-*O*-substituted benzyl 6-deoxy-α-L-talopyranosides **12** and **16** were later used as aglycons for the disaccharide synthesis.

Before satisfactory conditions were established for preparation of the 3,4-*O*-isopropylidene derivative **12**, several alternative routes to 3,4-di-*O*-substituted derivatives of **10** were explored using regioselective alkylation, in the presence of tetrabutylammonium bromide[17], or benzoylation, in the presence of molecular sieves[18], of the dibutylstannylene derivative of benzyl 4-*O*-benzyl-6-deoxy-α-L-talopyranoside (**19**). Compound **19** had been obtained crystalline by benzylation of **9** to give the crystalline 4-*O*-benzyl-2,3-*O*-isopropylidene derivative **18**, which was deacetonated with mild acid. In each case, regioselective reaction proceeded with preferential, but not exclusive, substitution at O-3 in **19**, and column-chromatographic separation was required for the isolation of pure products. Thus benzylation[17] of the stannylene derivative of **19** afforded **16** and the 2,4-di-*O*-benzyl ether **20** in 53 and 32% yield, respectively. The structure of the latter compound was established similarly by methylation (to give **21**), followed by hydrogenolysis to afford 6-deoxy-3-*O*-methyl-L-talose[19] (**39**), whose identity was confirmed from the mass spectrum of the derived, partially methylated alditol acetate **43**. Similarly, allylation[17] of the stannylene derivative of **19** afforded the 3- (**23**) and 2-allyl (**22**) ethers in 54 and 35% yields, respectively. The structures of these compounds were confirmed by benzylation to give respectively compounds **24** and **15**, which on *O*-deallylation afforded **20** and **16**, respectively. In both regioselective reactions, no 2,3,4-tri-substituted ethers were formed and no starting material **19** remained. Regioselective benzoylation[18] of the stannylene derivative of **19** gave the 3- (**28**) and 2-*O*-benzoyl (**27**) derivatives in 66 and 24% yields, respectively, with complete

utilization of **19** but no formation of the 2,3-di-*O*-benzoyl derivative **29**. Compound **29** was prepared separately by treatment of **19** with an excess of benzoyl chloride in pyridine. Compounds **28** and **27** were prepared separately from the allyl ethers **22** and **23** *via* compounds **25** and **26**, respectively, with subsequent *O*-deallylation over palladium-on-charcoal in acidic solution. In contrast, selective benzoylation of **19** with benzoyl chloride in pyridine at −40° showed little selectivity, and gave, after chromatography on a column of silica gel, **29, 28,** and **27** in 36, 8, and 25% yields, respectively, with recovery of unchanged **19** (20%).

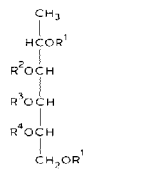
The synthesis of the disaccharide **36** was performed most simply by the method of Hanessian and Banoub[20] by condensation of **12** with **3** in the presence of silver trifluoromethanesulfonate (triflate) and 1,1,3,3-tetramethylurea. The reaction gave a mixture shown by t.l.c. to contain benzyl 6-deoxy-3,4-*O*-isopropylidene-2-*O*-(2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl)-α-L-talopyranoside (**31**) as the major product, accompanied by traces of the marginally slower-moving, unreacted **12**, which could not be removed by column chromatography. Therefore, the mixture was *O*-deacetylated and the product chromatographed on a column of silica gel to give, in 91% yield, benzyl 6-deoxy-3,4-*O*-isopropylidene-2-*O*-(α-L-rhamnopyranosyl)-α-L-talopyranoside (**30**), which on acetylation gave **31**. Deacetonation of **30** with mild acid furnished the crystalline benzyl glycoside **32**, from which the parent disaccharide **36** was obtained on hydrogenolysis. Methylation linkage-analysis of **36** gave 2,3,4-tri-*O*-methylrhamnitol diacetate (**46**) and 6-deoxy-3,4-di-*O*-methyltalitol triacetate (**44**), thus confirming the presence of the (1→2)-interglycosidic linkage in **36**. Reduction of **36** with sodium borohydride afforded the crystalline disaccharide alditol **40**, which was acetylated to give the crystalline hepta-*O*-acetyl deivative **41**. The ^{13}C-n.m.r. spectra of the disaccharide benzyl glycoside **32**, the disaccharide alditol **40**, and its heptaacetate **41** gave values of 169–172 Hz for the ^{13}C-1–H-1 coupling constants, which confirmed the formation of an α-L-rhamnopyranosyl linkage[21].

In an alternative synthesis of **36**, compound **16** was condensed with **3** in 1:1 benzene–nitromethane in the presence of mercuric cyanide to give a mixture. T.l.c.



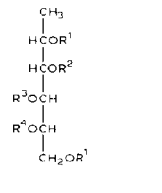
40–41

40 R = H
41 R = Ac



42–45

42 $R^1 = R^2 = R^3 = Ac, R^4 = Me$
43 $R^1 = R^2 = R^4 = Ac, R^3 = Me$
44 $R^1 = R^4 = Ac, R^2 = R^3 = Me$
45 $R^1 = R^2 = R^3 = R^4 = Ac$



46–47

46 $R^1 = Ac, R^2 = R^3 = R^4 = Me$
47 $R^1 = R^2 = R^4 = Ac, R^3 = Me$

examination showed the formation of benzyl 3,4-di-*O*-benzyl-6-deoxy-2-*O*-(2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl)-α-L-talopyranoside (**34**) as the major product, accompanied by a trace of a marginally slower-moving component. Purification of **34** by column chromatography was not successful, so that the mixture was *O*-deacetylated and the resulting mixture fractionated on a column of silica gel to give benzyl 3,4-di-*O*-benzyl-6-deoxy-2-*O*-(α-L-rhamnopyranosyl)-α-L-talopyranoside (**33**) in 84% yield. Acetylation of **33** gave **34**. Hydrogenolysis of **33** gave **36**, which was reduced with sodium borohydride to furnish **40**, whose physical constants were good agreement with those of the compound prepared earlier from reaction of **12** with **3**.

Treatment of **33** with trimethyl orthobenzoate in the presence of *p*-toluenesulfonic acid, followed by benzoylation with benzoyl chloride in pyridine, and acid-catalyzed rearrangement of the orthobenzoate[22] furnished **35** in 75% yield. The location of benzoyl substituents in **35** was established by methylation with diazomethane–boron trifluoride etherate[23], followed by successive hydrogenolysis, hydrolysis, reduction, and acetylation to give an equimolar mixture of 6-deoxytalitol pentaacetate (**45**) and 3-*O*-methylrhamnitol tetraacetate (**47**). The partially substituted disaccharide glycoside **35**, or analogues prepared similarly, should serve as common aglycons for the synthesis of complete oligosaccharide chains from the glycopeptidolipid antigens of the MAIS group of organisms.

EXPERIMENTAL

General methods. — Organic solutions were dried with anhydrous sodium sulfate. Solutions were evaporated, at a temperature <50°, under diminished pressure. Benzene, dichloromethane, *N*,*N*-dimethylformamide, dimethyl sulfoxide, nitromethane, pyridine, and 1,1,3,3-tetramethylurea were distilled over calcium hydride, and stored over molecular sieves 4Å. The sodium hydride purchased as a dispersion in mineral oil was washed several times with petroleum ether before use. Melting points were determined with a Yanagimoto micro-melting point apparatus and are uncorrected. Optical rotations were measured with an Applied Electronic automatic polarimeter, and i.r. spectra were recorded with a Shimadzu IR-2C spectrometer. N.m.r. spectra were recorded with a Varian A-60A spectrometer; tetramethylsilane (in chloroform-*d* and dimethyl sulfoxide-d_6) and 4,4-dimethyl-4-silapentane-1-sulfonate (in deuterium oxide) were the internal standards. ^{13}C-N.m.r. spectra were recorded at 100.6 MHz with a Bruker WH 400 spectrometer; tetramethylsilane (in chloroform-*d*) and acetone-d_6 (in deuterium oxide) were the internal standards. G.l.c. was performed on a packed column of 3% of silicone–polyester copolymer ECNSS-M on Gas-Chrom Q at 200° or on an OV-225 S.C.O.T. column at 170°. Mass spectra were determined for samples introduced by direct insertion or from a g.l.c. capillary column of silicone DB5-15N (permanently bonded OV-54) attached by a jet separator to a VG Micromass 16F mass spectrometer, which was operated with an inlet temperature of 250°, an ionization po-

tential of 70 eV, and an ion-source temperature of ~250°. Microanalyses were performed by the Guelph Chemical Laboratories, Guelph, Ontario. T.l.c. was performed on Silica gel 60, No. 7731 (Merck); spots were made visible by spraying the plates with 10% sulfuric acid, followed by heating. Column chromatography was performed on Silica gel 60, No. 7734 (Merck). The following solvent combinations (v/v) were used: (*1*) 4:1, (*2*) 3:1, (*3*) 7:3, (*4*) 2:1, (*5*) 3:2, and (*6*) 2:3 hexane–ethyl acetate, (*7*) 19:1, (*8*) 9:1, (*9*) 4:1, and (*10*) 2:1 benzene–ethyl acetate, (*11*) 4:1, (*12*) 3:1, and (*13*) 3:2 chloroform–methanol, and (*14*) 9:1 and (*15*) 4:1 benzene–ethanol.

*Benzyl α-*L*-rhamnopyranoside* (**5**). — To a stirred solution of L-rhamnose (**1**) monohydrate (25 g) in pyridine (100 mL) was added, dropwise at 0°, acetic anhydride (100 mL) during 20 min. The mixture was allowed to warm to room temperature and then kept overnight. The solvents were evaporated, the last traces being removed by repeated evaporation of toluene from the residue, to give 1,2,3,4-tetra-*O*-acetyl-L-rhamnopyranose (**2**) as a syrup (45 g, ~100%), $[\alpha]_D^{24}$ −63.1° (*c* 1.5, chloroform); t.l.c. (solvent *9*): R_F 0.44 and 0.40 (a mixture of the α and β anomers); lit.[7] $[\alpha]_D^{25}$ −61.7° (*c* 2.7, chloroform). To a chilled (to 0°) solution of **2** (40.2 g) in dichloromethane and freshly distilled acetic acid (40 mL) was added a saturated (at 0°) solution of hydrogen bromide in acetic acid (80 mL). The mixture was kept for 3 h at 0°, and then distilled with dichloromethane (300 mL). The solution was washed successively with iced water, aqueous sodium hydrogencarbonate, and water, dried, and evaporated to a syrup, which crystallized from ether–petroleum ether to give 2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl bromide (**3**) as needles (37.6 g, 88%), m.p. 64–65°, $[\alpha]_D^{24}$ −171.5° (*c* 1.1, chloroform); lit.[8] m.p. 71–72°, $[\alpha]_D$ −169°. To a stirred mixture of dry benzyl alcohol (19 mL, 183.2 mmol), mercuric cyanide (22.9 g, 90.6 mmol), and powdered molecular sieves 4 Å (10 g) in dichloromethane (150 mL) was added dropwise over a period of 1 h a solution of **3** (32.0 g, 90.6 mmol) in dichloromethane (150 mL). The mixture was stirred for 16 h at room temperature, filtered through a layer of Celite, and the inorganic solids were washed with dichloromethane. The combined filtrate and washings were washed successively with water, aqueous potassium bromide, aqueous sodium hydrogencarbonate, and water, and dried. The solution was evaporated, and remaining benzyl alcohol was removed *in vacuo* at 80°by repeated evaporation of water. The resulting white mass was recrystallized from ethanol to give benzyl 2,3,4-tri-*O*-acetyl-α-L-rhamnopyranoside (**4**) as needles (28.3 g, 82%), m.p. 111–112°, $[\alpha]_D^{27}$ −77.1° (*c* 2.4, chloroform); lit.[6] m.p. 110°, $[\alpha]_D^{20}$ −73° (*c* 1, chloroform). Compound **4** (25 g) was treated in abs. methanol (100 mL) with methanolic M sodium methoxide (3 mL). The solution was kept for 1 h at room temperature, made neutral with Amberlite IR-120 (H^+) ion-exchange resin, filtered, and evaporated to a syrup, which crystallized from ethyl acetate to give **5** (19.9 g, 95%), m.p. 74–75°, $[\alpha]_D^{27}$ −66.8° (*c* 1.0, water); lit.[6] m.p. 76°, $[\alpha]_D^{20}$ −63° (*c* 1.0, water).

*Benzyl 2,3-*O*-isopropylidene-α-*L*-rhamnopyranoside* (**6**). — A mixture of **5** (12.3 g), 2,2-dimethoxypropane (25 mL), and *p*-toluenesulfonic acid (260 mg) was

stirred for 45 min at room temperature. The acid was made neutral with Amberlite IR-400 (OH^-) ion-exchange resin, and the solution evaporated. The residue was recrystallized from petroleum ether to give **6** (12.8 g, 90%), m.p. 74–75°, $[\alpha]_D^{27}$ −53.1° (*c* 1.9, chloroform); lit.[9] m.p. 73–75°, $[\alpha]_D$ −55° (*c* 1, chloroform).

*Benzyl 6-deoxy-2,3-O-isopropylidene-α-*L*-lyxo-hexopyranosid-4-ulose* (**7**). — To a solution of **6** (5.0 g) in alcohol-free chloroform (50 mL) were added water (80 mL), potassium periodate (6.0 g), potassium carbonate (0.65 g), and ruthenium dioxide (1.0 g). The mixture was stirred vigorously at room temperature, and the progress of the reaction monitored by t.l.c. (solvent *1*; R_F 0.17 for **6** and R_F 0.47 for **7**). Further additions of potassium periodate (each 0.5 g) were made after 3, 4, and 5 h, respectively, and, after 7 h, t.l.c. indicated complete disappearance of **6**. The oxidation was terminated by adding 2-propanol (20 mL) and stirring the mixture for 20 min. The mixture was filtered through a Celite pad, and the filter was washed with chloroform (50 mL). The organic layer was separated, and the aqueous layer extracted with chloroform (3 × 30 mL). The combined extracts were dried and evaporated to a syrup, which was fractionated on a column of silica gel (42 × 600 mm) with solvent *1* to give **7** as a colorless syrup (3.78 g, 76%), $[\alpha]_D^{20}$ −115.9° (*c* 2.2, chloroform); ν_{max}^{film} 1755 cm^{-1} (C=O); n.m.r. data (chloroform-*d*): δ 7.53 (s, 5 H, Ph), 5.05 (s, 1 H, H-1), 3.53 (AB q, 2 H, *J* 12.0 Hz, PhCH_2), 1.48, 1.36 (s, each 3 H, CMe_2), and 1.40 (d, 3 H, $J_{5,6}$ 6.0 Hz, Me).

*Benzyl 4-O-acetyl-6-deoxy-2,3-O-isopropylidene-α-*L*-talopyranoside* (**8**). — (*a*) Sodium borohydride (0.3 g) was added in portions during 15 min to a vigorously stirred solution (cooled to 0°) of **7** (4.10 g) in dry methanol (100 mL). The mixture was stirred for 20 min at room temperature, when t.l.c. (solvent *10*) showed the disappearance of **7**, and the formation of **9** (R_F 0.57) and **6** (R_F 0.51) in ~95:5 ratio. The mixture was boiled for 10 min under reflux to decompose the excess of the hydride, evaporated, and the residue extracted with chloroform. The solution was washed successively with water, 2% acetic acid, sodium hydrogencarbonate, and water, and then dried, and evaporated to a syrup. Methanol was repeatedly evaporated from the syrup, and the resulting syrup was acetylated with 1:1 (v/v) acetic anhydride–pyridine (40 mL) overnight at room temperature. The mixture was evaporated and toluene evaporated from the residue to give a crystalline mass, which was recrystallized from ethanol to afford **8** (4.01 g, 85%), m.p. 96–97°, $[\alpha]_D^{27}$ −64.4° (*c* 1.6, chloroform); n.m.r. data (chloroform-*d*): δ 7.35 (s, 5 H, Ph), 4.64 (AB q, 2 H, *J* 12.0 Hz, PhCH_2), 2.15 (s, 3 H, Ac), 1.50, 1.33 (s, each 3 H, CMe_2), and 1.20 (d, 3 H, $J_{5,6}$ 6.5 Hz, Me).

Anal. Calc. for $C_{18}H_{24}O_6$: C, 64.27; H, 7.19. Found: C, 64.33; H, 7.13.

(*b*) The product mixture obtained by oxidation of **6** (1.0 g) with ruthenium tetraoxide, without chromatographic separation, was treated with sodium borohydride (20 mg) in methanol (20 mL), followed by 1:1 (v/v) acetic anhydride–pyridine (10 mL), to give **8** (0.92 g, 81%), m.p. and mixed m.p. 96–97° (ethanol), $[\alpha]_D^{24}$ −64.0° (*c* 1.2, chloroform).

(*c*) To a stirred solution of **6** (10.0 g) in *N*,*N*-dimethylformamide (60 mL)

containing phosphorus pentaoxide (20 g) was added dropwise dimethyl sulfoxide during 30 min, during which time the temperature rose to ~30°. The suspension was stirred for 2 h at ambient temperature (25–30°), and for 5 h at 60°. The mixture was cooled, and poured cautiously into ice–water (500 mL) containing potassium carbonate (20 g). After evolution of gas had ceased, the mixture was extracted with hexane (5 × 100 mL). The extracts were combined, washed with aqueous sodium chloride (2 × 50 mL), dried, and evaporated to a syrup. T.l.c. (solvent *1*) showed the presence of **9**, and two minor products (R_F 0.54 and 0.25), in addition to traces of unchanged **6** (R_F 0.02). Treatment of the syrup in methanol (220 mL) with sodium borohydride (0.5 g), followed by acetylation with 1:1 (v/v) acetic anhydride–pyridine (90 mL), as described in method *a*, gave **8** (8.22 g, 72%), m.p. and mixed m.p. 96–97° (ethanol), $[\alpha]_D^{27}$ −64.3° (*c* 1.5, chloroform).

*Benzyl 6-deoxy-2,3-O-isopropylidene-α-*L*-talopyranoside* (**9**). — A solution of **8** (14.3 g) in dry methanol (100 mL) and dichloromethane (50 mL) was treated with methanolic M sodium methoxide (5 mL). The mixture was kept for 5 h at room temperature, made neutral with Amberlite-120 (H^+) ion-exchange resin, the resin filtered off, and the filtrate evaporated to give **9** (11.5 g, 92%), m.p. 41–42° (cyclohexane), $[\alpha]_D^{27}$ −68.2° (*c* 2.0, chloroform); n.m.r. data (chloroform-*d*): δ 7.33 (s, 5 H, Ph), 5.14 (s, 1 H, H-1), 4.64 (AB q, 2 H, *J* 12.0 Hz, PhCH_2), 2.23 (d, 1 H, $J_{4,4\text{-}OH}$ 7.0 Hz, exchangeable with D_2O, 4-OH), 1.58, 1.36 (s, each 3 H, CMe_2), and 1.31 (d, 3 H, $J_{5,6}$ 6.0 Hz, Me).

Anal. Calc. for $C_{16}H_{22}O_5$: C, 65.29; H, 7.53. Found: C, 65.28; H, 7.64.

*Benzyl 6-deoxy-α-*L*-talopyranoside* (**10**). — A solution of **9** (7.11 g) in acetic acid (36 mL) was heated to 80°, water (24 mL) was added in small portions, and the mixture was stirred for 1 h at 80°. The solvents were evaporated, and the last traces of the solvents were removed with the aid of repeated addition and evaporation of toluene. The residue was crystallized from hexane to give **10** (5.59 g, 91%), m.p. 87–88°, $[\alpha]_D^{20}$ −94.4° (*c* 1.7, water).

Anal. Calc. for $C_{13}H_{18}O_5$: C, 61.41; H, 7.13. Found: C, 61.33; H, 7.21.

Acetylation of **10** (0.21 g) with 1:1 (v/v) acetic anhydride–pyridine (3 mL) overnight at room temperature gave benzyl 2,3,4-tri-*O*-acetyl-6-deoxy-α-L-talopyranoside (**11**) as a syrup (0.29 g, 94%), $[\alpha]_D^{26}$ −90.4° (*c* 2.0, chloroform); t.l.c. (solvent *9*): R_F 0.45; n.m.r. data (chloroform-*d*): δ 7.33 (s, 5 H, Ph), 4.63 (AB q, 2 H, *J* 12.0 Hz, PhCH_2), 2.15, 2.12, 1.98 (s, each 3 H, 3 OAc), and 1.19 (d, 1 H, $J_{5,6}$ 6.0 Hz, Me).

*6-Deoxy-*L*-talose* (**37**). — Compound **10** (0.62 g) was dissolved in acetic acid and hydrogenated in the presence of 10% palladium-on-carbon (0.5 g) overnight at room temperature and normal pressure. The catalyst was filtered off through a Celite pad, and washed with methanol. The combined filtrate and washings were evaporated, and the residue was crystallized from ethanol–acetone to give **37** (0.32 g, 80%), m.p. 124–125°, $[\alpha]_D^{27}$ −19.9° (*c* 0.5, water); lit.[13] m.p. 126–127°, $[\alpha]_D^{20}$ −20.5° (*c* 2.28, water).

*Benzyl 6-deoxy-3,4-O-isopropylidene-α-*L*-talopyranoside* (**12**). — A mixture

of **10** (6.0 g), 2,2-dimethoxypropane (13 mL), and *p*-toluenesulfonic acid (100 mg) was stirred for 1 h at room temperature. The acid was made neutral with Amberlite IR-400 (OH^-) ion-exchange resin, the resin was filtered off and washed with dichloromethane, and the combined filtrate and washings were evaporated to a syrup, which was shown by t.l.c. (solvent 5) to be composed of two components having R_F values of 0.40 (**9**) and 0.27 (**12**), in addition to traces of unreacted **10**. The mixture was fractionated on a column (43 × 480 mm) of silica gel. Elution with solvent *6* gave **9** (0.56 g, 8%), m.p. and mixed m.p. 40–41° (cyclohexane), $[\alpha]_D^{23}$ −67.0° (*c* 1.3, chloroform). Further elution of the column with solvent *6* afforded **12** (5.28 g, 76%), m.p. 75–76° (petroleum ether), $[\alpha]_D^{20}$ −97.7° (*c* 2.7, chloroform); n.m.r. data (chloroform-*d*): δ 7.32 (s, 5 H, Ph), 2.66 (d, 1 H, $J_{2,2\text{-}OH}$ 7.0 Hz, exchangeable with D_2O, 2-OH), 1.50, 1.34 (s, each 3 H, C-Me_2), and 1.23 (d, 3 H, $J_{5,6}$ 6.0 Hz, Me).

Anal. Calc. for $C_{16}H_{22}O_5$: C, 65.29; H, 7.53. Found: C, 65.36; H, 7.40.

A portion of **12** was successively methylated, hydrolyzed with 0.5M sulfuric acid for 5 h at 100°, reduced with sodium borohydride, and acetylated to give 1,3,4,5-tetra-*O*-acetyl-6-deoxy-2-*O*-methyl-L-talitol (**42**), which was homogeneous on g.l.c., and whose mass spectrum showed prominent fragment-ions at *m/z* 113, 117, 129, 173, 201, and 275.

Benzyl 2-O-allyl-6-deoxy-α-L-talopyranoside (**14**). — Sodium hydride (1.2 g) was added to a solution of **12** (3.50 g) in *N*,*N*-dimethylformamide (40 mL), and the mixture was stirred for 1 h at room temperature, and then cooled at 0°. Allyl bromide (2.1 mL) was added, and the mixture was stirred for 3 h at room temperature. Methanol was added to decompose the excess of the hydride, and most of the solvent was evaporated off. A solution of the residue in chloroform was washed with water, dried, and evaporated to a syrup, which was chromatographed on a column (22 × 30 mm) with solvent *4* to give benzyl 2-*O*-allyl-6-deoxy-3,4-*O*-isopropylidene-α-L-talopyranoside (**13**) as a syrup (3.49 g, 88%), $[\alpha]_D^{20}$ −75.3° (*c* 1.5, chloroform). Treatment of **13** (3.19 g) in acetic acid (30 mL) with water (20 mL) for 2 h at 80°, as described for the preparation of **10**, gave **14** (2.52 g, 90%), m.p. 86–87° (petroleum ether), $[\alpha]_D^{22}$ −88.6° (*c* 1.9, chloroform).

Anal. Calc. for $C_{16}H_{22}O_5$: C, 65.29; H, 7.53. Found: C, 65.25; H, 7.54.

Benzyl 3,4-di-O-benzyl-6-deoxy-α-L-talopyranoside (**16**). — To a solution of **14** (2.89 g) in *N*,*N*-dimethylformamide (40 mL) was added sodium hydride (1.4 g), and the mixture was stirred for 1 h at room temperature, and then cooled to 0°. To this mixture was added benzyl bromide (7 mL), and the mixture was stirred overnight at room temperature, and processed as described for the preparation of **13**. The resulting syrup was fractionated on a column (22 × 330 mm) of silica gel with solvent *1* to give benzyl 2-*O*-allyl-3,4-di-*O*-benzyl-6-deoxy-α-L-talopyranoside (**15**) as a syrup (3.86 g, 82%), $[\alpha]_D^{20}$ −32.0° (*c* 1.7, chloroform).

(*a*) A solution of **15** (1.07 g) in boiling ethanol–benzene–water (8:3:1, 30 mL) containing tris(triphenylphosphine)rhodium chloride (60 mg) and 1,4-diazabicyclo[2.2.2]octane (0.3 g) was stirred overnight under reflux, and then evapo-

rated to dryness. A solution of the residue in chloroform was washed successively with water, M hydrochloric acid, aqueous sodium hydrogencarbonate, and water, dried, and evaporated. The residue was dissolved in acetone (18 mL) and M hydrochloric acid (2 mL), and the mixture was boiled for 30 min under reflux, cooled, made neutral with aqueous sodium hydrogencarbonate, evaporated, and extracted with chloroform. The extract was washed with water, dried, and evaporated to a syrup, which was chromatographed on a column (22 ×250 mm) of silica gel with solvent *2* to give **16** as a syrup (0.80 g, 80%), $[\alpha]_D^{18}$ −55.5° (*c* 2.1, chloroform).

(*b*) A mixture of **15** (0.57 g) and 10% palladium-on-carbon (0.5 g) in ethanol–acetic acid–water (3:1:1, 15 mL) was stirred for 20 h at 80°. The catalyst was filtered off, and the filtrate was evaporated to a syrup, which was fractionated on a column (22 ×200 mm) of silica gel with solvent *2* to give **16** (0.35 g, 76%), $[\alpha]_D^{20}$ −54.2° (*c* 1.2, chloroform).

Benzyl 3,4-di-O-benzyl-6-deoxy-2-O-methyl-α-L-talopyranoside (**17**). — A solution of **16** (1.1 g) in *N*,*N*-dimethylformamide (15 mL) was stirred for 1 h at room temperature in the presence of sodium hydride (0.2 g), and then cooled to 0°. Methyl iodide (1 mL) was added, and the mixture was stirred for 3 h at room temperature and processed as described for the preparation of **13**. The resulting syrup was eluted from a column (22 × 30 mm) of silica gel with solvent *9* to give **17** as a syrup (0.97 g, 85%), $[\alpha]_D^{20}$ −25.5° (*c* 1.3, chloroform); n.m.r. data (chloroform-*d*): δ 3.54 (s, 3 H, OMe).

6-Deoxy-2-O-methyl-L-talose (**38**). — Hydrogenation of **17** (0.81 g) in acetic acid (3 mL) in the presence of 10% palladium-on-charcoal (0.2 g), as described for the preparation of **37**, followed by elution of the residue from a column (18 × 220 mm) of silica gel with solvent *11*, gave **38** as a syrup (0.26 g, 82%), $[\alpha]_D^{20}$ −6.0° (*c* 2.0, water). A portion of **38** was reduced with sodium borohydride and then acetylated to give **42**, which was identical (g.l.c.–m.s.) to the previously prepared sample.

Benzyl 4-O-benzyl-6-deoxy-2,3-O-isopropylidene-α-L-talopyranoside (**18**). — Compound **9** (9.92 g) was treated in *N*,*N*-dimethylformamide (100 mL) with sodium hydride (2.0 g), followed by benzyl bromide (6 mL). Processing as described for the preparation of **13** gave **18** (11.15 g, 86%), m.p. 92–93° (petroleum ether), $[\alpha]_D^{26}$ −25.2° (*c* 1.6, chloroform); n.m.r. data (chloroform-*d*): δ 7.32–7.29 (m, 10 H, 2 Ph), 5.00 (d, 1 H, $J_{1,2}$ 1.5 Hz, H-1), 1.53, 1.34 (s, each 3 H, CMe_2), and 1.21 (d, 3 H, $J_{5,6}$ 6.5 Hz, Me).

Anal. Calc. for $C_{23}H_{28}O_5$: C, 71.85; H, 7.34. Found: C, 72.05; H, 7.34.

Benzyl 4-O-benzyl-6-deoxy-α-L-talopyranoside (**19**). — Treatment of **18** (10.15 g) in acetic acid (84 mL) with water (56 mL) for 1 h at 80°, as described for the preparation of **10**, gave **19** (8.36 g, 92%), m.p. 86–87° (petroleum ether), $[\alpha]_D^{26}$ −99.6° (*c* 2.2, chloroform): n.m.r. data (chloroform-*d*): δ 7.32–7.30 (m, 10 H, 2 Ph), and 1.23 (d, 3 H, $J_{5,6}$ 6.5 Hz, Me).

Anal. Calc. for $C_{20}H_{24}O_5$: C, 69.75; H, 7.02. Found: C, 69.91; H, 6.95.

Regioselective benzylation of **19**. — A mixture of **19** (2.35 g, 6.8 mmol) and

dibutyltin oxide (1.70 g, 6.8 mmol) in benzene (150 mL) was stirred and boiled for 3 h under reflux with azeotropic removal of water by a Dean–Stark condenser. After ~1 h, the mixture became clear, and it was evaporated to ~100 mL. Tetrabutylammonium bromide (2.20 g, 6.8 mmol) and benzyl bromide (1.78 mL, 15.1 mmol) were added, and the mixture was boiled for 20 h under reflux, after which time t.l.c. (solvent *2*) showed the presence of **16** (R_t 0.37) and **20** (R_t 0.28). The mixture was evaporated to dryness and water evaporated from the residue to give a syrup, which was dissolved in chloroform. The solution was washed with water, dried, and evaporated, and the residue was fractionated on a pre-packed column (32 × 570 mm) of silica gel. Elution with solvent *2* gave **16** as a syrup (1.57 g, 53%), $[\alpha]_D^{18}$ −54.0° (*c* 1.1, chloroform). Subsequent elution with solvent *4* afforded benzyl 2,4-di-*O*-benzyl-6-deoxy-α-L-talopyranoside (**20**) (0.95 g, 32%), m.p. 83–84° (ether–petroleum ether), $[\alpha]_D^{20}$ −62.4° (*c* 1.7, chloroform).

Anal. Calc. for $C_{27}H_{30}O_5$: C, 74.63; H, 6.96. Found: C, 74.80; H, 6.88.

Compound **20** (0.9 g) was treated in *N*,*N*-dimethylformamide (15 mL) with sodium hydride (0.15 g), followed by methyl iodide (1 mL). Purification of the resulting syrup by column chromatography with solvent *9* afforded benzyl 2,4-di-*O*-benzyl-6-deoxy-3-*O*-methyl-α-L-talopyranoside (**21**) as a syrup (0.82 g, 88%), $[\alpha]_D^{20}$ −48.8° (*c* 1.7, chloroform); n.m.r. data (chloroform-*d*): δ 3.34 (s, 3 H, OMe).

6-Deoxy-3-O-methyl-L-talose (**39**). — Hydrogenation of **21** (0.7 g), followed by purification by column chromatography, as described for **37**, gave **39** as a syrup (0.24 g, 86%), $[\alpha]_D^{18}$ −29.6° (*c* 1.1, water); lit.[19] −19.4°. A portion of **39** was reduced with sodium borohydride and acetylated to give 1,2,4,5-tetra-*O*-acetyl-3-*O*-methyl-L-talitol (**43**), which was homogeneous on g.l.c., and whose mass spectrum showed prominent fragment-ions at *m/z* 129, 143, 189 and 203.

Regioselective allylation of **19**. — Treatment of **19** (6.0 g, 17.4 mmol) in benzene (300 mL) with dibutyltin oxide (4.34 g, 17.4 mmol), followed by allyl bromide (15.1 mL, 174 mmol) and tetrabutylammonium bromide (5.62 g, 17.4 mmol), as described earlier, gave a mixture, which was shown by t.l.c. (solvent *8*) to contain **23** (R_t 0.34) and **22** (R_t 0.24). The mixture was processed as described earlier and fractionated on a pre-packed column (45 × 700 mm) of silica gel. Elution with solvent *8* gave benzyl 3-*O*-allyl-4-*O*-benzyl-6-deoxy-α-L-talopyranoside (**23**) as a syrup (3.62 g, 54%), $[\alpha]_D^{20}$ −44.2° (*c* 2.2, chloroform). Further elution with solvent *9* afforded benzyl 2-*O*-allyl-4-*O*-benzyl-6-deoxy-α-L-talopyranoside (**22**) as a syrup (2.35 g, 35%), $[\alpha]_D^{20}$ −72.9° (*c* 1.3, chloroform). Benzylation of **22** (0.89 g), as described earlier, followed by purification on a column (22 × 250 mm) of silica gel with solvent *1*, gave **15** (0.95 g, 86%), $[\alpha]_D^{18}$ −33.3° (*c* 1.5, chloroform).

Benzyl 3-O-allyl-2,4-di-O-benzyl-6-deoxy-α-L-talopyranoside (**24**). — Benzylation of **23** (1.35 g), as described previously, followed by chromatography on a column (22 × 360 mm) of silica gel with solvent *1*, gave **24** as a syrup (1.36 g, 81%), $[\alpha]_D^{18}$ −52.7° (*c* 1.4, chloroform).

O-Deallylation of **24** (1.18 g), as described for **15** (method *b*), followed by chromatography on a column (24 × 300 mm) of silica gel with solvent *2*, gave **20**

(0.77 g, 71%), m.p. 83–84° (ether–petroleum ether), $[\alpha]_D^{18}$ −63.1° (*c* 1.5, chloroform).

Benzyl 2-O-allyl-3-O-benzoyl-6-deoxy-α-L-talopyranoside (**25**). — Benzoyl chloride (0.8 mL) was added dropwise to a stirred solution of **22** (0.91 g) in pyridine (5 mL) at 0°, and the mixture was allowed to attain room temperature, and then kept for 5 h. The mixture was treated with a small amount of ice–water, kept for 2 h at room temperature, and evaporated to dryness. A solution of the residue in chloroform was washed successively with water, M hydrochloric acid, aqueous sodium hydrogencarbonate, and water, dried, and evaporated to a syrup, which was chromatographed on a column (22 ×330 mm) of silica gel with solvent *1* to give **25** as a syrup (0.96 g, 83%), $[\alpha]_D^{20}$ −79.7° (*c* 1.2, chloroform).

Benzyl 3-O-allyl-2-O-benzoyl-4-O-benzyl-6-deoxy-α-L-talopyranoside (**26**). — Treatment of **23** (1.10 g) in pyridine (6 mL) with benzoyl chloride (1 mL) at 0°, followed by processing, as just described, and purification on a column (22 × 270 mm) of silica gel with solvent *1*, gave **26** as a syrup (1.19 g, 85%), $[\alpha]_D^{18}$ −26.4° (*c* 1.3, chloroform).

Benzyl 2-O-benzoyl-4-O-benzyl-6-deoxy-α-L-talopyranoside (**27**). — *O*-Deallylation of **26** (0.84 g), as described for **15** (method *b*), followed by chromatography on a column (22 ×300 mm) of silica gel with solvent *4*, gave **27** (0.58 g, 75%), m.p. 109–110° (ethanol), $[\alpha]_D^{20}$ −40.0° (*c* 1.7, chloroform).

Anal. Calc. for $C_{27}H_{28}O_6$: C, 72.30; H, 6.29. Found: C, 72.33; H, 6.29.

Benzyl 3-O-benzoyl-4-O-benzyl-6-deoxy-α-L-talopyranoside (**28**). — *O*-Deallylation of **25** (0.76 g), as described for **15** (method *b*), followed by chromatographic purification, afforded **28** as a syrup (0.49 g, 70%), $[\alpha]_D^{20}$ −97.4° (*c* 0.9, chloroform).

Benzyl 2,3-di-O-benzoyl-4-O-benzyl-6-deoxy-α-L-talopyranoside (**29**). — Treatment of **19** (0.48 g) in pyridine (5 mL) with benzoyl chloride (0.5 mL), as described for the preparation of **25**, gave **29** (0.64 g, 83%), m.p. 76–78° (ether–petroleum ether), $[\alpha]_D^{20}$ −29.5° (*c* 1.8, chloroform).

Anal. Calc. for $C_{34}H_{32}O_7$: C, 73.90; H, 5.84. Found: C, 73.98; H, 5.78.

Regioselective benzoylation of **19**. — (*a*) A mixture of **19** (2.0 g) and dibutyltin oxide (1.45 g) in benzene (120 mL) was stirred for 3 h under reflux with continuous removal of water. The solution was evaporated to ~90 mL, and cooled. Powdered molecular sieves 4Å (5 g) and benzoyl chloride (0.74 mL) were added, and the mixture was stirred overnight at room temperature, after which time t.l.c. (solvent *8*) showed the presence of **28** (R_F 0.54) and **27** (R_F 0.45). The mixture was filtered off through a Celite pad, and the solids were washed with chloroform. The combined filtrate and washings were evaporated to a syrup, which applied to a prepacked column (38 ×470 mm) of silica gel. Elution with solvent *7* gave **28** (1.72 g, 66%), $[\alpha]_D^{26}$ −96.1° (*c* 1.0, chloroform). Further elution with solvent *8* afforded **27** (0.62 g, 24%), m.p. and mixed m.p. 108–109° (ethanol), $[\alpha]_D^{26}$ −40.6° (*c* 1.0, chloroform).

(*b*) Benzoyl chloride (0.56 mL, 4.8 mmol) was added over a period of 20 min

to a stirred solution of **19** (1.5 g, 4.4 mmol) in pyridine (60 mL) at −40°. The mixture was stirred for 1 h at −30°, 2 h at −20°, and overnight at 0°. T.l.c. (solvent *8*) showed the presence of **29** (R_F 0.61), **28** (R_F 0.54), **27** (R_F 0.45), and **19** (R_F 0.12). The mixture was processed as described for the preparation of **25**, and the resulting syrup fractionated on a pre-packed column (38 × 600 mm) of silica gel. Elution with solvent *7* gave **29** (0.87 g, 36%), m.p. and mixed m.p. 76–78°, $[\alpha]_D^{26}$ −30.0° (*c* 1.5, chloroform). Subsequent elution with solvent *7* afforded **28** (0.18 g, 8%), $[\alpha]_D^{26}$ −95.8° (*c* 1.1, chloroform). Further elution with solvent *8* gave **27** (0.48 g, 25%), m.p. and mixed m.p. 109–110°, $[\alpha]_D^{26}$ −39.5° (*c* 1.0, chloroform). Elution with methanol gave unchanged **19** (0.30 g, 20%).

Benzyl 6-deoxy-3,4-O-isopropylidene-2-O-(α-L-rhamnopyranosyl)-α-L-talopyranoside (**30**). — A solution of **3** (5.76 g, 16.3 mmol) in dichloromethane (20 mL) was added dropwise during 20 min to a stirred solution (cooled to −20°) of **12** (2.40 g, 8.2 mmol) in dichloromethane (30 mL) containing silver triflate (5.03 g, 19.6 mmol) and 1,1,3,3-tetramethylurea (4.71 mL, 39.4 mmol). After being stirred for 1 h at −20°, the mixture was allowed to warm to room temperature, and then stirred overnight. T.l.c. (1:1 hexane–ethyl acetate) showed the formation of **31** (R_F 0.44) as the major product, accompanied by a marginally slower-moving component (R_F 0.40) and traces of unreacted **12**. The solids were removed by filtration and washed with dichloromethane. The combined filtrate and washings were washed successively with water, aqueous sodium hydrogencarbonate, and water, dried, and evaporated. A solution of the residue in methanol (80 mL) was treated with methanolic M sodium methoxide (3 mL), and the mixture was processed as described for **8**. The resulting syrup was fractionated on a column (30 × 580 mm) of silica gel with solvent *15* to give **30** as a syrup (3.27 g, 91%), $[\alpha]_D^{20}$ −92.5° (*c* 1.6, chloroform); t.l.c. (solvent *15*): R_F 0.40; n.m.r. data (deuterium oxide): δ 7.31 (s, 5 H, Ph), 4.96 (s, 1 H, H-1′), 4.86 (d, 1 H, $J_{1,2}$ 6.0 Hz, H-1), 4.74, 4.51 (AB q, 2 H, *J* 11.6 Hz, PhCH_2), 1.49, 1.32 (s, each 3 H, C-Me$_2$), and 1.17–1.14 (2 overlapping d, 6 H, 2 Me).

Benzyl 6-deoxy-3,4-O-isopropylidene-2-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-α-L-talopyranoside (**31**). — Acetylation of **30** (0.25 g) with 1:1 (v/v) acetic anhydride–pyridine (3 mL) overnight at room temperature gave **31** as a syrup (0.26 g, 93%), $[\alpha]_D^{18}$ −101.5° (*c* 1.6, chloroform); n.m.r. data (chloroform-*d*): δ 7.33 (s, 5 H, Ph), 2.14, 2.03, 1.98 (s, each 3 H, 3 OAc), 1.52, 1.36 (s, each 3 H, CMe$_2$), 1.20, and 1.04 (d, each 3 H, $J_{5,6} = J_{5',6'} = 6.0$ Hz, 2 Me).

Benzyl 6-deoxy-2-O-(α-L-rhamnopyranosyl)-α-L-talopyranoside (**32**). — Treatment of **30** (2.54 g) in acetic acid (15 mL) with water (10 mL) for 1 h at 80°, as described for the preparation of **10**, gave **32** (2.13 g, 92%), m.p. 176–178° (ethanol), $[\alpha]_D^{20}$ −123.8° (*c* 1.5, water); n.m.r. data (deuterium oxide): δ 7.37 (s, 5 H, Ph), 4.95 (d, 2 H, $J_{1,2} = J_{1',2'} = \sim 1.5$ Hz, H-1,1′), 1.28, and 1.15 (d, each 3 H, $J_{5,6} = J_{5',6'} = 6.0$ Hz, 2 Me); δ_C 103.35 [$J_{C\text{-}1,H\text{-}1}$ 169.9 Hz (C-1 or C-1′)], 98.2 [*J* 170.3 Hz (C-1′ or C-1)].

Anal. Calc. for $C_{19}H_{28}O_9$: C, 56.99; H, 7.05. Found: C, 57.13; H, 7.12.

6-Deoxy-2-O-(α-L-rhamnopyranosyl)-L-talose (**36**). — Compound **32** (1.94 g) was hydrogenolyzed, as described for **10**, and the product was purified by elution from a column (22 × 320 mm) of silica gel with solvent *12* to give **36** as a hygroscopic solid (1.22 g, 81%), $[\alpha]_D^{20}$ −48.2° (*c* 1.4, water); t.l.c. (solvent *13*): R_F 0.50.

Anal. Calc. for $C_{12}H_{22}O_9$: C, 46.45; H, 7.15. Found: C, 46.46; H, 7.22.

Methylation of a portion of **36**, followed by hydrolysis, reduction with sodium borohydride, and acetylation, gave a 1:1 mixture of the peracetates of 6-deoxy-3,4-di-*O*-methyl-L-talitol (**44**) and 2,3,4-tri-*O*-methyl-L-rhamnitol (**46**), whose structures were confirmed by g.l.c.–m.s.

6-Deoxy-2-O-(α-L-rhamnopyranosyl)-L-talitol (**40**). — Compound **36** (0.62 g) was reduced with sodium borohydride (30 mg) in water (15 mL) overnight at room temperature. The solution was treated with Amberlite IR-120 (H^+) ion-exchange resin to decompose the excess of hydride, the resin was filtered off and washed with methanol, and the combined filtrate and washings were evaporated. Several additions and evaporations of methanol gave a syrup, which crystallized from ethanol to afford **40** (0.57 g, 92%), m.p. 113–116°, $[\alpha]_D^{20}$ −58.5° (*c* 0.3, water); n.m.r. data (deuterium oxide): δ_C 99.69 [$J_{C\text{-}1',H\text{-}1'}$ 168.9 Hz (C-1')].

Anal. Calc. for $C_{12}H_{24}O_9$: C, 46.15; H, 7.75. Found: C, 46.15; H, 7.70.

1,3,4,5-Tetra-O-acetyl-6-deoxy-2-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-L-talitol (**41**). — Acetylation of **40** (0.32 g) gave **41** (0.42 g, 86%), m.p. 114–115° (hexane–ether), $[\alpha]_D^{20}$ −70.3° (*c* 1.9, chloroform); n.m.r. data (chloroform-*d*): δ 2.19, 2.16, 2.08, 2.07, 2.05, 2.04, 1.98 (s, each 3 H, 7 OAc), 1.21 and 1.19 (d, each 3 H, $J_{5,6} = J_{5',6'} = 6.0$ Hz, 2 Me); δ_C 96.45 [$J_{C\text{-}1',H\text{-}1'}$ 171.7 Hz (C-1')].

Anal. Calc. for $C_{26}H_{38}O_{16}$: C, 51.48; H, 6.31. Found: C, 51.49; H, 6.33.

Benzyl 3,4-di-O-benzyl-6-deoxy-2-O-(α-L-rhamnopyranosyl)-α-L-talopyranoside (**33**). — A solution of **16** (3.5 g, 8.1 mmol) in 1:1 benzene–nitromethane (200 mL) was concentrated until 75 mL of the solvent mixture had distilled, and the mixture was cooled to 45°. Mercuric cyanide (3.05 g, 12.1 mmol) and **3** (4.27 g, 12.1 mmol) were added, and the mixture was stirred overnight at 45°, and then evaporated. The residue was extracted with chloroform and the extract was washed successively with water, aqueous potassium bromide, sodium hydrogencarbonate, and water, and then dried and evaporated. A solution of the residual syrup in dry methanol (50 mL) was treated with M sodium methoxide (2 mL), and the mixture was processed as described for the preparation of **9**. The residue was fractionated on a pre-packed column (42 × 530 mm) of silica gel with solvent *14* to give **33** as a syrup (3.93 g, 84%), $[\alpha]_D^{20}$ −76.2° (*c* 2.1, chloroform); t.l.c. (solvent *15*): R_F 0.53; n.m.r. data (dimethyl sulfoxide-d_6): δ 7.33 (s, 15 H, 3 Ph), 1.20, and 1.06 (d, each 3 H, $J_{5,6} = J_{5',6'} = 6.0$ Hz).

Anal. Calc. for $C_{33}H_{40}O_9$: C, 68.26; h, 6.94. Found: C, 68.25; H, 6.90.

Hydrogenolysis of **33** (0.44 g) and subsequent reduction with sodium borohydride gave **40** (0.17 g, 71%), m.p. and mixed m.p. 113–116° (ethanol), $[\alpha]_D^{20}$ −57.2° (*c* 0.5, water).

Benzyl 3,4-di-O-benzyl-6-deoxy-2-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyrano-

syl)-α-L-*talopyranoside* (**34**). — Acetylation of **33** (0.25 g) gave **34** as a syrup (0.26 g, 87%), $[\alpha]_D^{20}$ −54.8° (*c* 0.8, chloroform); n.m.r. data (chloroform-*d*): δ 7.30 (s, 15 H, 3 Ph), 2.08, 1.98, 1.92 (s, each 3 H, 3 OAc), 1.27, and 1.10 (d, each 3 H, $J_{5,6} = J_{5',6'} = 6.0$ Hz, 2 Me).

Anal. Calc. for $C_{30}H_{46}O_{12}$: C, 66.28; H, 6.56. Found: C, 66.16; H, 6.72.

*Benzyl 3,4-di-O-benzyl-6-deoxy-2-O-(2,4-di-O-benzoyl-α-*L*-rhamnopyranosyl)-α-*L*-talopyranoside* (**35**). — A solution of **33** (3.0 g) in *N,N*-dimethylformamide (25 mL) containing trimethyl orthobenzoate (5 mL) and *p*-toluenesulfonic acid (50 mg) was stirred for 6 h at room temperature. Triethylamine (0.5 mL) was added and the mixture was evaporated. To a cooled solution of the residue in pyridine (15 mL) was added benzoyl chloride (1.2 mL), and the mixture was stirred for 2 h at room temperature. Ice–water was added, and the mixture was evaporated to a syrup, which was dissolved in chloroform. The solution was washed with water, dried, and evaporated. The residue was dissolved in 80% acetic acid (30 mL), and the mixture was stirred for 15 min at room temperature, evaporated, and toluene was evaporated from the residue to give a syrup, which was purified by elution from a column (43 × 520 mm) of silica gel with solvent *3*, to afford **35** as an amorphous powder (3.06 g, 75%), $[\alpha]_D^{15}$ −21.5° (*c* 1.5, chloroform); t.l.c. (solvent *4*): R_F 0.44; n.m.r. data (chloroform-*d*): δ 8.22–7.20 (m, 30 H, 5 Ph), 1.94 (d, 1 H, $J_{3',3'\text{-OH}}$ 7.0 Hz, exchangeable with D_2O, 3'-OH), 1.37, and 1.19 (d, each 3 H, $J_{5,6} = J_{5',6'} = 6.0$ Hz, 2 Me).

Anal. Calc. for $C_{47}H_{48}O_{11}$: C, 71.56; H, 6.13. Found: C, 71.40; H, 6.15.

Methylation[23] of a portion of **35** with diazomethane–boron trifluoride etherate, followed by successive *O*-debenzoylation, hydrogenolysis, hydrolysis, reduction with sodium borohydride, and acetylation, gave a 1:1 mixture of the peracetates of 6-deoxy-L-talitol (**45**) and 3-*O*-methyl-L-rhamnitol (**47**), whose structures were determined by g.l.c.–m.s.

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