C-Nucleoside Studies. Part II.[1,2] Pentofuranosylethynes from 2,3-*O*-Isopropylidene-D-ribose

By **J. Grant Buchanan,* Allan D. Dunn,** and **Alan R. Edgar,** Department of Chemistry, Heriot-Watt University, Riccarton, Currie, Edinburgh EH14 4AS

Ethynylmagnesium bromide reacted with 2,3-*O*-isopropylidene-D-ribose (1) in tetrahydrofuran to give, in 70% yield, 1,2-dideoxy-4,5-*O*-isopropylidene-D-*allo*-hept-1-ynitol (3), which was converted into its 7-trityl ether (4). The structures of the ethynes (3) and (4) were shown by conversion into 1,2-dideoxy-4,5-*O*-isopropylidene-7-*O*-trityl-D-*allo*-hept-1-enitol (7) which, by hydrolytic and ozonolytic cleavage, afforded allose, identified by reduction to allitol. Treatment of the trityl ether (4) with toluene-*p*-sulphonyl chloride in pyridine yielded 2,3-*O*-isopropylidene-5-*O*-trityl-α-D-ribofuranosylethyne (9), acidic hydrolysis of which gave crystalline-α-D-ribofuranosylethyne (11). 3-*O*-Benzoyl-1,2-dideoxy-4,5-*O*-isopropylidene-6-*O*-methylsulphonyl-7-*O*-trityl-D-*allo*-hept-1-ynitol (14), on reaction with sodium methoxide, gave 2,3-*O*-isopropylidene-5-*O*-trityl-α-L-lyxofuranosylethyne (17).

The ethynes (3) and (4) were oxidised, at the position α to the triple bond by manganese dioxide; reduction of the resulting hemiacetals (29b) and (34b) with sodium borohydride yielded mainly the D-*altro*-isomers (5) and (6). Oxidation of the ethyne (3) with sodium periodate afforded crystalline 5,6-dideoxy-2,3-*O*-isopropylidene-L-*ribo*-hex-5-ynofuranose (31b), which was also one of the products of oxidation with manganese dioxide.

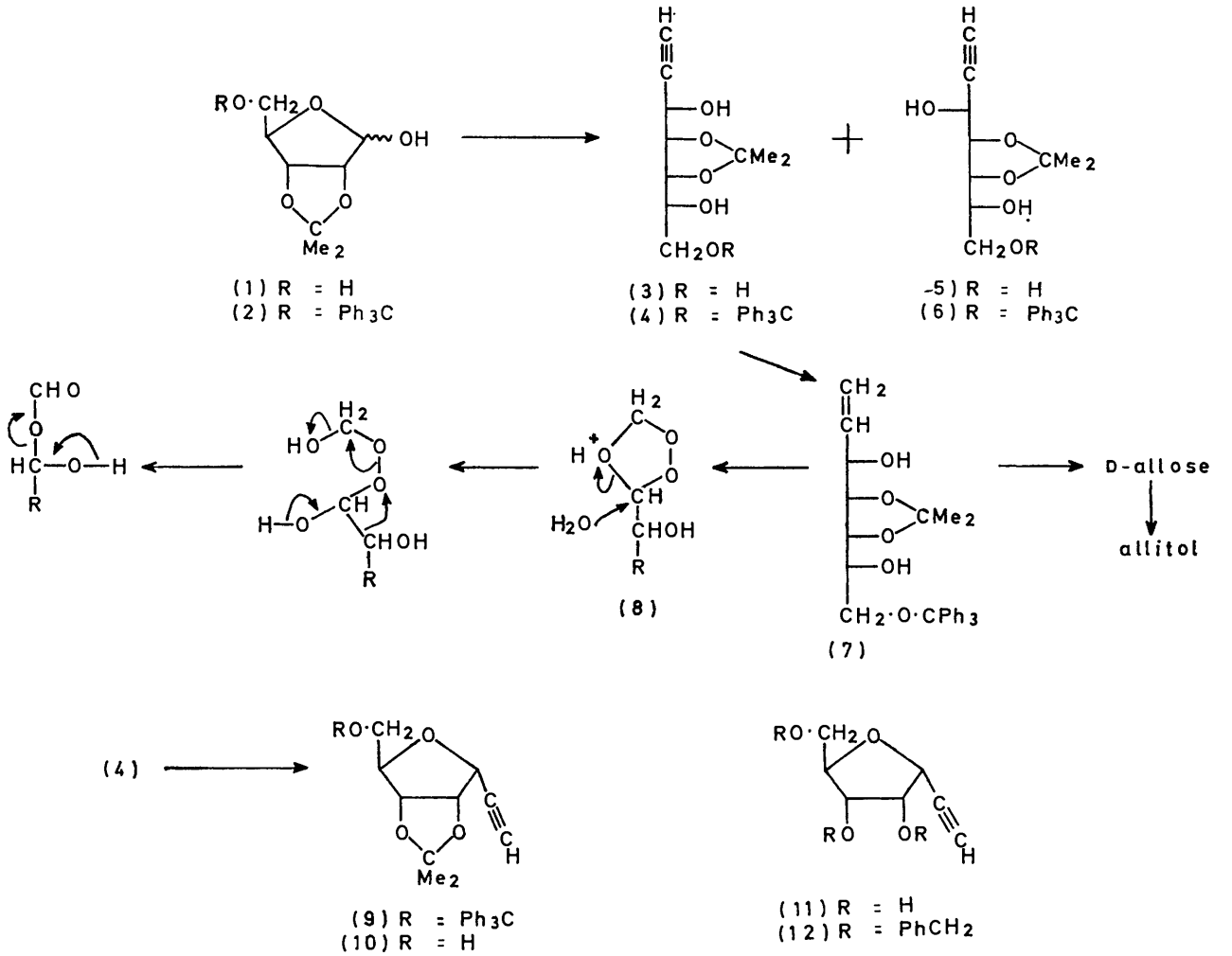
Other transformations are described, including the synthesis of 2,3-*O*-isopropylidene-5-*O*-trityl-β-D-ribofuranosylethyne (20) and the corresponding β-L-*lyxo*-isomer (35).

In Part I [1] we described syntheses of the tribenzyl ethers of α- and β-D-ribofuranosylethyne, from 2,3,5-tri-*O*-benzyl-D-ribofuranose. We wished to have available a range of derivatives of the D-ribofuranosylethynes with protecting groups of differing types, and now give an account of some syntheses from 2,3-*O*-isopropylidene-D-ribose (1).[2]

There are several examples of the carbohydrate field of the reaction of organomagnesium compounds with hemiacetals in which the aldehyde group becomes unmasked.[1-5] 2,3-*O*-Isopropylidene-D-ribose,[6,7] which probably exists mainly as the furanose (1),[8] reacted with ethynylmagnesium bromide in tetrahydrofuran to give a pure crystalline triol [(3) or (5)] in 70% yield. There was evidence, discussed below, for the formation of a small amount of a non-crystalline second epimer. Treatment of the triol with triphenylmethyl (trityl) chloride in pyridine afforded (81%) a crystalline ether [(4) or (6)] which was also obtained by reaction of the trityl derivative (2) [6] with ethynylmagnesium bromide. The configuration of the products was established as D-*allo* [*i.e.* (3) and (4)] by reduction of the propargylic alcohol (4) with lithium aluminium hydride,[9] to give the crystalline alkene (7), followed by acidic hydrolysis and ozonolysis [9,10] to yield allose. No altrose, which would have arisen from the compounds of the D-*altro*-series [(5) and (6)] was detected chromatographically. The identity of allose was proved by borohydride reduction to give crystalline allitol. Some ribose was also present in the ozonolysis product (*cf.* ref. 10) and may arise by the process (8) suggested to us by Dr. M. J. Power.

[1] Part I, J. G. Buchanan, A. R. Edgar, and M. J. Power, *J.C.S. Perkin I*, 1974, 1943.
[2] Preliminary communication, J. G. Buchanan, A. D. Dunn, and A. R. Edgar, *Carbohydrate Res.*, 1974, **36**, C5.
[3] D. Horton and F. O. Swanson, *Carbohydrate Res.*, 1970, **14**, 159.
[4] W. S. Chilton, W. C. Lontz, R. B. Roy, and C. Yoda, *J. Org. Chem.*, 1971, **36**, 3222.
[5] R. B. Roy and W. S. Chilton, *J. Org. Chem.*, 1971, **36**, 3242.
[6] P. A. Levene and E. T. Stiller, *J. Biol. Chem.*, 1933, **102**, 187.
[7] N. A. Hughes and P. R. H. Speakman, *Carbohydrate Res.*, 1965, **1**, 171.
[8] S. J. Angyal, *Angew. Chem. Internat. Edn.*, 1969, **8**, 157.
[9] R. Hems, D. Horton, and M. Nakadate, *Carbohydrate Res.*, 1972, **25**, 205.
[10] D. Horton and J. M. J. Tronchet, *Carbohydrate Res.*, 1966, **2**, 315.

The ring closure of the diol (4) by means of toluene-*p*-sulphonyl chloride in pyridine[1] was then studied. There were two possible products, the α-D-ribofuranosylethyne (9) and the α-L-lyxofuranosylethyne (17), the reasonable assumption being made that inversion would occur at the site of closure. Only one product was formed, in 90% yield, which was converted into a crystalline triol by removal of the trityl and isopropylidene groups.



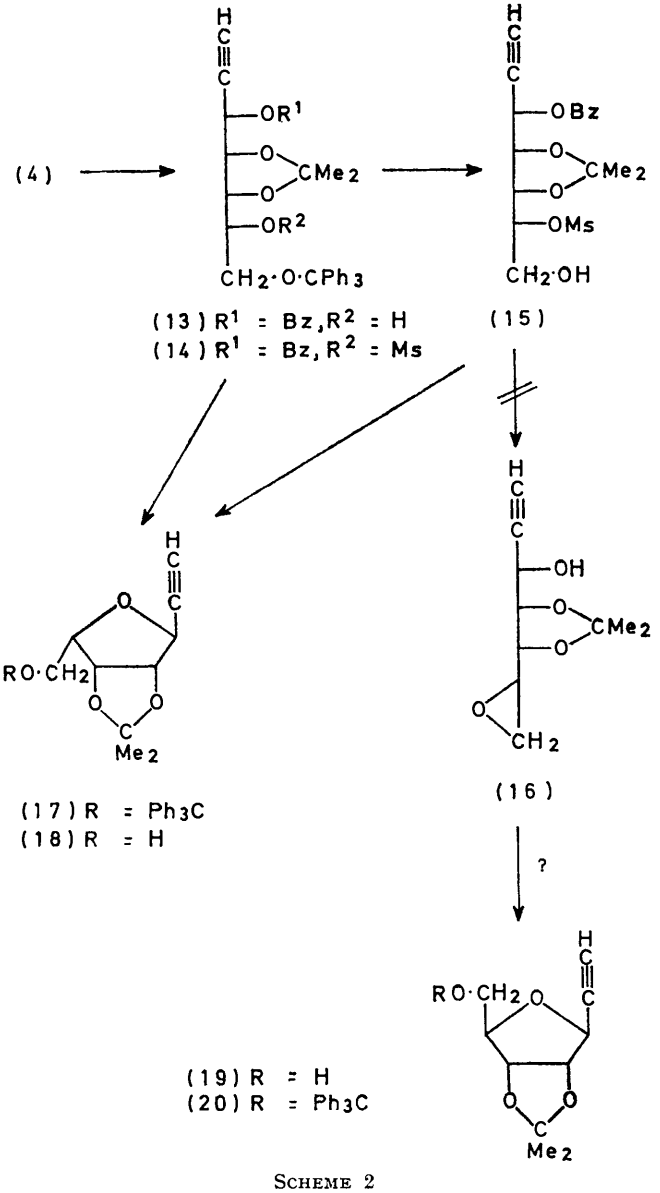
SCHEME 1

Benzylation yielded a crystalline tribenzyl ether, identical with the major product of the reaction of 2,3,5-tri-*O*-benzyl-D-ribofuranosyl chloride with ethynylmagnesium bromide.[1] This indicates that the product of ring closure of the diol (4) with toluene-*p*-sulphonyl chloride has a *ribo*-configuration, which must be produced by sulphonylation at O-3 followed by intramolecular ring closure from O-6. The product of such a sequence must of necessity be the α-D-ribofuranosylethyne (9), and this confirms the validity of our original assignment, based on Hudson's rules, of the α-D-*ribo*-configuration (12) to the major product of the reaction of the D-ribofuranosyl chloride with ethynylmagnesium bromide.[1] The crystalline isopropylidene compound (10) was obtained during these transformations (see Experimental section).

Since most of the naturally occurring *C*-nucleosides are in the β-series,[11,12] we wished to convert the D-*allo*-diol (4) into derivatives [*e.g.* (19) and (20)] of β-D-ribofuranosylethyne. The first route studied is shown in Scheme 2. The crucial step was the conversion of the methanesulphonate (15) into the L-*talo*-epoxide (16) and thence by epoxide rearrangement[13,14] into the β-D-ribosylethyne (19). Selective benzoylation of the diol (4) gave, in good yield, a crystalline monobenzoate, whose ^{1}H n.m.r. spectrum showed it to be the expected 3-

[11] R. J. Suhadolnik, 'Nucleoside Antibiotics,' Wiley–Interscience, New York, 1970.
[12] G. E. Gutowski, M. O. Chaney, N. D. Jones, R. L. Hamill, F. A. Davis, and R. D. Miller, *Biochem. Biophys. Res. Comm.*, 1973, **51**, 312.
[13] J. S. Brimacombe, *Fortschr. Chem. Forsch.*, 1970, **14**, 367.
[14] J. G. Buchanan, in M.T.P. International Review of Science, Organic Chemistry Series One, ed. D. H. Hey, vol. 7, ed. G. O. Aspinall, Butterworths, 1973, p. 31.

benzoate (13); the low-field methine proton signal (δ 6·03) appeared as a double doublet, irradiation at the frequency of which caused the acetylenic doublet at



SCHEME 2

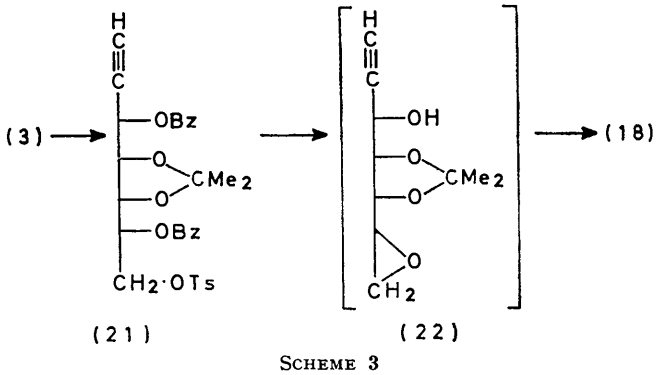
δ 2·49 (J 2 Hz) to collapse to a singlet. Treatment of the monobenzoate (13) with methanesulphonyl chloride in pyridine gave the crystalline sulphonate (14) in high yield. When the sulphonate (14) was treated with methanolic sodium methoxide, ring closure took place with formation of a product differing from the D-*ribo*-isomer (9), which was clearly the α-L-lyxofuranosylethyne (17). This provides confirmatory evidence for the location of the ester groups in the sulphonate (14).

Controlled acidic hydrolysis of the trityl ether (14) afforded the sulphonate (15) with retention of the isopropylidene group. It was hoped that subsequent treatment with methanolic sodium methoxide would give the 6,7-L-*talo*-epoxide (16), but instead the α-L-lyxofuranosylethyne (18) was formed rapidly. The structure of the product was proved by tritylation to give the ether (17). We have not investigated the details of this reaction, but the first step must be the loss of the benzoyl group from O-3, either by methanolysis or by intramolecular migration to O-7.

A reaction which does involve a 6,7-epoxide intermediate, and its subsequent intramolecular ring opening, led to another synthesis of the α-lyxosylethyne (18) (Scheme 3). The triol (3) was converted into the crystalline triester (21) by sequential reaction with toluene-*p*-sulphonyl chloride (1 mol. equiv.) and benzoyl chloride. When this ester was treated with sodium methoxide in methanol the α-L-lyxosylethyne (18) was formed (66%), clearly by way of the 6,7-D-*allo*-epoxide (22).

In Part I,[1] the formation of derivatives of β-D-ribofuranosylethyne by ring closure of acyclic derivatives possessing the D-*altro*-configuration was described. The conversion of the D-*allo*-triol (3) and its trityl ether (4) into compounds of the D-*altro*-series, *i.e.* the ethynes (26), (27), (5), and (6), was therefore explored, as outlined in Schemes 4—6.

The triol (3), when treated with phosgene in pyridine, afforded the cyclic carbonate (23) in 62% yield. *p*-Tolylsulphonylation then gave the sulphonate (24), reaction of which with sodium benzoate in dimethylformamide [15] did not yield the expected 3-benzoate (26) of D-*altro*-configuration. The major product, isolated crystalline in 45% yield, was the 3-ene (25) arising by elimination.[14,16] The *E*-isomer (25) is that to be expected from an anti-elimination of the E_2C type; [14] the ^{1}H n.m.r. spectrum confirmed the structure in that H-6 appeared to be deshielded by the π-electron system of the triple bond. We also treated the carbonate (23)



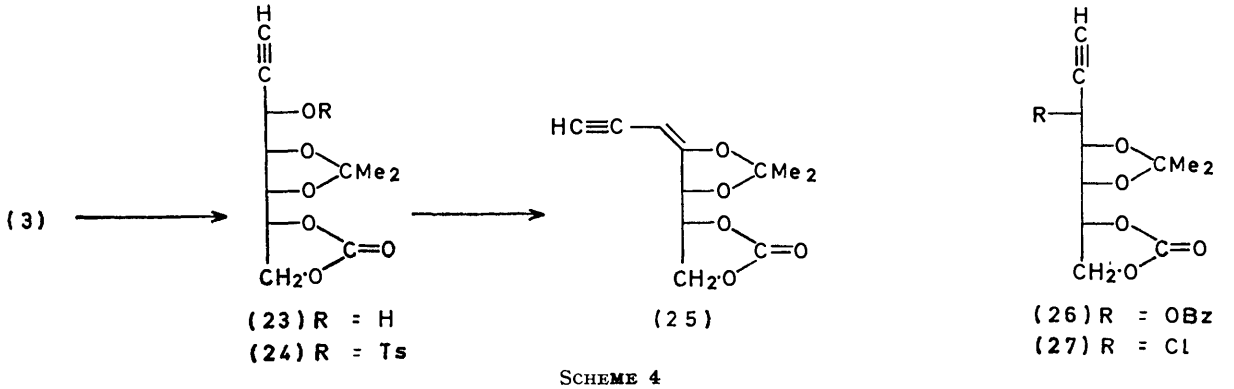
SCHEME 3

with the triphenyl phosphine–carbon tetrachloride reagent [17] in an attempt to prepare the 3-chloro-derivative (27), but the reaction was complex and this approach was abandoned.

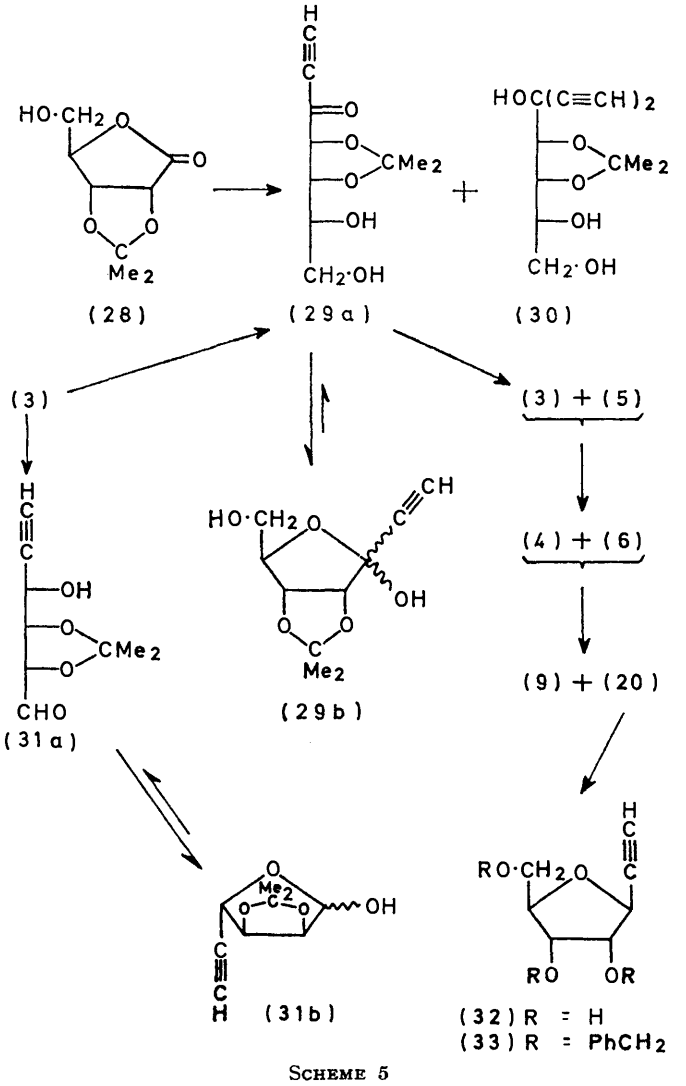
[15] J. L. Godman and D. Horton, *J. Org. Chem.*, 1968, **33**, 872.
[16] M. A. Bukhari, A. B. Foster, and J. M. Webber, *J. Chem. Soc.*, 1964, 2514.
[17] J. B. Lee and T. J. Nolan, *Canad. J. Chem.*, 1966, **44**, 1331.

Ogura [18,19] and Géro [20] and their colleagues have used 2,3-*O*-isopropylidene-D-ribono-1,4-lactone (28) and its derivatives as a starting material for the synthesis of *C*-ribosyl derivatives. When the lactone (28) was treated with ethynyl magnesium bromide (*ca.* 2 mol. equiv.) there were two major products, some starting material remaining unchanged (Scheme 5). The product with lower R_F value (t.l.c.) crystallised and was shown to be the tertiary alcohol (30) by spectroscopic and analytical data. The other crystalline product had the same R_F value as the lactone (28) and could not be separated from it by chromatography or by crystallisation. It appeared to be the cyclic form (29b) of the initially formed ketose (29a). The mixture was treated with sodium borohydride and the product chromatographed on silica gel. A syrupy mixture of triols (3) and (5) was obtained and was treated with trityl chloride in pyridine. After purification over silica gel the mixture of ethers (4) and (6) was treated with toluene-*p*-sulphonyl chloride in pyridine to effect cyclisation. The major product had a higher R_F value on t.l.c. relative to the α-D-ribosylethyne (9), which was also present, and was isolated by chromatography on silica gel. The β-D-ribosyl structure (20) was proved by acidic hydrolysis to the triol (32), which was identified by benzylation to give the known ether (33). The other cyclisation products were not examined further (see below).

This synthesis gave a very poor overall yield, but it did indicate that reduction of the sugar (29b) with sodium borohydride gave an appreciable amount of the D-*altro*-triol (5). We therefore studied the oxidation of the triol (3) by manganese dioxide [21-23] in the hope that the sugar (29b) would result (Scheme 5). Two crystalline products were formed and could be separated from each other by chromatography. One was the expected sugar (29b), isolated in 25% yield. The second had a high R_F value on t.l.c. Its analytical and spectroscopic properties suggested that it was the sugar (31b) arising by oxidative cleavage of the C(6)–C(7) bond in the triol (3) to give the aldehyde (31a), followed by hemiacetal formation. This structure was confirmed when the same sugar was produced in high yield by oxidation of



SCHEME 4

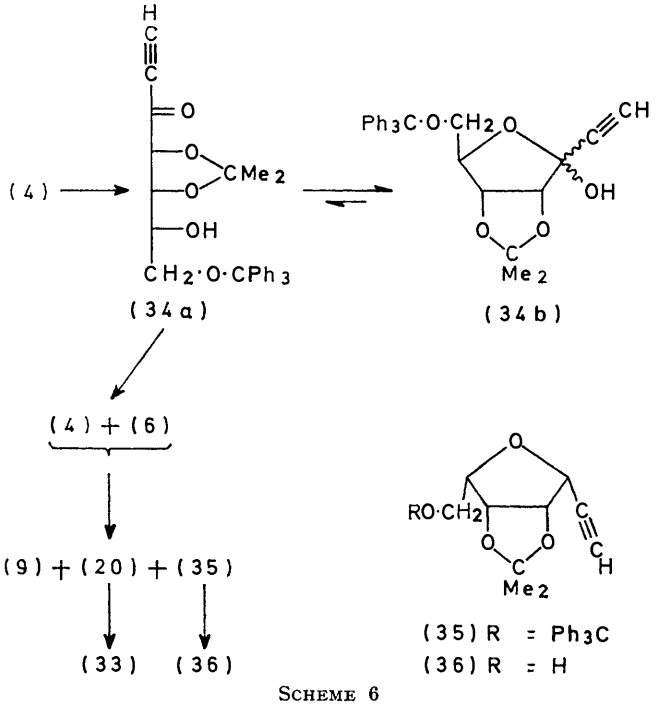


SCHEME 5

[18] H. Ogura, H. Takahashi, and T. Itoh, *J. Org. Chem.*, 1972, **37**, 72.
[19] H. Ogura and H. Takahashi, *J. Org. Chem.*, 1974, **39**, 1374.
[20] A. M. Sépulchre, A. Gateau-Olesker, G. Lukacs, G. Vass, S. D. Géro, and W. Voelter, *Tetrahedron Letters*, 1972, 3945.
[21] J. Attenburrow, A. F. B. Cameron, J. H. Chapman, R. M. Evans, B. A. Hems, A. B. A. Jansen, and T. Walker, *J. Chem. Soc.*, 1952, 1094.
[22] R. M. Evans, *Quart. Rev.*, 1959, **13**, 61.
[23] U. Lerch, M. G. Burdon, and J. G. Moffatt, *J. Org. Chem.*, 1971, **36**, 1507.

the triol (3) with sodium periodate. It was now clear that if the cleavage reaction could be prevented it should be possible to oxidise the 3-hydroxy-group in good yield, and the trityl ether (4) was the obvious choice of substrate.

The ether (4) was treated with manganese dioxide, followed by borohydride, and then toluene-*p*-sulphonyl chloride in pyridine. The reaction mixture consisted mainly of three products, which were separated by chromatography. The β-ethyne (20) was obtained in 20% overall yield from the D-*allo*-triol (3), together with the α-ethyne (9) (10%) and the β-L-lyxofuranosylethyne (35) (10%). The structure of the β-D-ribosylethyne



SCHEME 6

(20) was shown by comparison with the earlier sample and by conversion into the tribenzyl ether (33).[1] The β-L-lyxosylethyne (35) was subjected to acidic hydrolysis and then treatment with acetone and sulphuric acid to yield the crystalline isopropylidene compound (36), identified by comparison with its enantiomer of known structure.[2]

The α-D-ribosylethyne (9) must have arisen from the *allo*-diol (4) as before; the β-D-ribosylethyne (20) and β-L-lyxosylethyne (35) must both have been derived from the D-*altro*-diol (6). When the cyclisation reaction was monitored by t.l.c., it was observed that the ethynes (20) and (35) were formed more slowly than (9). It appears, therefore, that toluene-*p*-sulphonylation at O-3 occurs more slowly in the *altro*-diol (6) than in the *allo*-diol (4) and that some attack at O-6 of the *altro*-diol (6) takes place as a competitive reaction, leading, by cyclisation, to the β-L-lyxosylethyne (35). It is interesting that no *altro*-3,6-disulphonate was observed, in contrast to the corresponding compound in the benzyl series.[1] Although the cyclisation to an all-*cis*-β-*lyxo*-arrangement is unfavourable,[14,24,25] the presence of the dioxolan ring probably assists the intramolecular pathway.[26]

These results were disappointing so far as effecting a good preparation of the β-ribosylethynes (19), (20), and (32) was concerned, but compounds in both the α-D-*ribo*- and α-L-*lyxo*-series are now readily available.

From the products of reaction of the ribofuranose (1) with ethynylmagnesium bromide only the D-*allo*-triol (3) was isolated in crystalline form. In the light of the work on the D-*altro*-isomers just described it appeared that chromatography could not be used to separate the triols (3) and (5) or the diols (4) and (6). The syrupy residue from the Grignard reaction was therefore treated with trityl chloride in pyridine, and the crude mixture of trityl ethers, (4) and (6), was subjected to cyclisation conditions. By chromatography, a low yield of the β-ethyne (20) was obtained [0·8% from the isopropylidene compound (1)], together with more of the α-ethyne (9) (7%).

The strong preference for the formation of the D-*allo*-isomer [(3) and (4)] in the reaction of the acetals (1) and (2) with ethynylmagnesium bromide was unexpected in view of the behaviour of 2,3:5,6-di-*O*-isopropylidene-D-mannofuranose towards this reagent.[4] Our reinvestigation [2] of the latter system has shown that the assignment of configuration [4] to the major product is in error.

EXPERIMENTAL

I.r. spectra were measured for potassium bromide discs or for films, using a Perkin-Elmer 257 or 157G spectrophotometer. U.v. spectra were measured on a Pye–Unicam SP 800 spectrometer. Mass spectra were recorded with an A.E.I. MS902 or MS30 spectrometer. N.m.r. spectra were measured on a Perkin-Elmer R12B spectrometer at 60 MHz or a Varian HA-100D or JEOL MH100 spectrometer at 100 MHz. Tetramethylsilane was used as internal standard in deuteriated organic solvents, and sodium 3-trimethylsilylpropane-1-sulphonate in deuterium oxide. Specific rotations refer to room temperature (20—25 °C) and were measured using a Bendix-NPL 143D automatic polarimeter (path length 1 cm).

Evaporations were carried out under reduced pressure (rotary evaporator). Light petroleum refers to the fraction of b.p. 60—80°. M.p.s are corrected, unless stated otherwise. Adsorption chromatography was carried out using silica gel (Merck; 70—230 mesh ASTM); when trityl ethers were being chromatographed triethylamine (0·1%) was added to all solvents.[27] For t.l.c. Kieselgel G (Merck) was used as adsorbent; carbohydrates were detected with anisaldehyde–sulphuric acid [28] or with sulphuric acid. Paper chromatography was carried out using Whatman No. 1 paper, and butan-1-ol–pyridine–water (3 : 1 : 1) as solvent; free sugars were detected by means of aniline

[24] B. G. Hudson and R. Barker, *J. Org. Chem.*, 1967, **32**, 3650.
[25] J. Defaye and D. Horton, *Carbohydrate Res.*, 1970, **14**, 128, and earlier papers.
[26] A. Gateau, A.-M. Sépulchre, and S. D. Géro, *Compt. rend.*, 1971, **273C**, 1649.
[27] F. W. Parrish, personal communication, 1967.
[28] E. Stahl and U. Kaltenbach, *J. Chromatog.*, 1961, **5**, 166.

phthalate [29] and non-reducing glycols by sodium periodate and Schiff's reagent.[30]

1,2-*Dideoxy*-4,5-O-*isopropylidene*-D-allo-*hept*-1-*ynitol* (3).—Ethylmagnesium bromide [from magnesium (19 g) and ethyl bromide (130 g)] in dry tetrahydrofuran (350 ml) was added dropwise to tetrahydrofuran (350 ml) saturated with acetylene, under constant stirring, with acetylene bubbling into the solution.[31] The addition took place over 2 h and addition of acetylene was continued for a further 30 min. 2,3-*O*-Isopropylidene-D-ribose (1) [7] (5·0 g) in dry tetrahydrofuran (50 ml) was added dropwise to this solution, with continuous passage of acetylene. Twenty-five minutes after completion of the addition, t.l.c. showed only a trace of the sugar (1) and after 1 h none remained. The mixture was stirred overnight, treated with aqueous 10% ammonium chloride (50 ml), and filtered through Celite. The precipitate was washed with ethyl acetate and the combined filtrate dried with a large quantity of sodium sulphate. After filtration the solvent was evaporated off to leave a thick brown syrup (5·91 g), which crystallised on addition of benzene. Recrystallised from benzene, the *triol* (3) (3·98 g, 70%) had m.p. 100—101°, $[\alpha]_D$ −63·6° (*c* 1·24 in EtOH), $\nu_{max.}$ (KBr) 3290 (≡CH), 2120 (C≡C), 3350br (OH), and 1390 and 1380 cm^{-1} (both CMe_2); δ (100 MHz; [$^2H_6$]-acetone) 1·32, 1·40 (6H, two s, CMe_2), 2·84 (1H, d, $J_{1,3}$ 2 Hz, H-1), and 3·2—5·4 (9H, m); *m/e* 216 (M^+) and 201 (M − 15) (Found: C, 55·5; H, 7·5. $C_{10}H_{16}O_5$ requires C, 55·6; H, 7·4%).

The mother liquors from the above crystallisations were combined and evaporated to yield a syrup (A) (1·84 g), which was converted into a mixture of 2,3-*O*-isopropylidene-5-*O*-trityl-β-D-ribofuranosylethyne (20) and the α-anomer (9) as described below.

1,2-*Dideoxy*-4,5-O-*isopropylidene*-7-O-*trityl*-D-allo-*hept*-1-*ynitol* (4).—(*a*) The triol (3) (1·0 g) was dissolved in pyridine (10 ml), trityl chloride (2·1 g, 1·63 mol. equiv.) was added, and the mixture was kept at 85° for 3·5 h. T.l.c. [light petroleum–ether (1 : 1)] showed the absence of starting material. Ethanol (100 ml) was added, and after 0·5 h solvents were removed *in vacuo*. The product was isolated from the residue by means of chloroform and the resulting syrup (2·98 g) subjected to chromatography on silica gel (40 g) (eluant light petroleum–ether). Light petroleum–ether (6 : 4) eluted the *trityl ether* (4) (1·72 g, 81%), m.p. 122—122·5° (from ether–light petroleum), $[\alpha]_D$ −0·9° (*c* 1·1 in $CHCl_3$) (the specific rotation given in ref. 2 is incorrect); $\nu_{max.}$ (KBr) 3300 (≡C–H), 2130 (C≡C), 1385 and 1370 (both CMe_2), 3400 (OH), 3090, 3060, 3030, 1610, 1500, and 705 cm^{-1} (all Ph); δ (100 MHz; $CDCl_3$) 1·32 (6H, s, CMe_2), 2·47 (1H, d, $J_{1,3}$ 2 Hz, H-1), 3·0—4·9 (8H, m), and 7·0—7·7 (15H, m, Ph) (Found: C, 75·8; H, 6·5. $C_{29}H_{30}O_5$ requires C, 76·0; H, 6·55%).

(*b*) 2,3-*O*-Isopropylidene-5-*O*-trityl-D-ribofuranose (2) [6,32] (1·0 g) in dry tetrahydrofuran (10 ml) was added to a solution of ethynylmagnesium bromide [31] [from ethyl bromide (5 ml) and magnesium (1·1 g)] in tetrahydrofuran (240 ml). After 46 h the mixture was treated with aqueous 10% ammonium chloride (100 ml) and the organic phase separated and dried (Na_2SO_4). The solvent was evaporated off to leave a yellow oil which crystallised from chloroform–light petroleum. The *trityl ether* (4) (0·59 g, 55%), m.p. 122—122·5°, was indistinguishable (i.r. and n.m.r. spectra; t.l.c.) from that described in (*a*).

1,2-*Dideoxy*-4,5-O-*isopropylidene*-7-O-*trityl*-D-allo-*hept*-1-*enitol* (7).—The ethyne (4) (125 mg) in ether (25 ml) was heated under reflux with lithium aluminium hydride (300 mg) for 3·5 h. The mixture was cooled in ice, and the excess of reagent destroyed by cautious addition of aqueous 10% ammonium chloride (10 ml). The mixture was filtered, the ether layer separated and dried (Na_2SO_4), and the ether removed *in vacuo* to leave a syrup (108 mg). T.l.c. [benzene–ether (4 : 1)] revealed the presence of a new compound of higher R_F value, together with unchanged acetylene. The mixture was purified by preparative layer chromatography (p.l.c.) [benzene–ether (5 : 1)]; recrystallisation from ether–light petroleum afforded the pure *ethene* (7) (60 mg, 48%), m.p. 153°, $[\alpha]_D$ +19·4° (*c* 0·62 in $CHCl_3$); $\nu_{max.}$ (KBr) 1650sh (C=C), 1390 and 1375 (both CMe_2), 3060, 3030, 1600, 1500, and 705 cm^{-1} (all Ph) (no acetylenic absorptions); δ (100 MHz; $CDCl_3$) 1·26 (6H, s, CMe_2), 3·0—4·4 (8H, m), 5·1—6·3 (3H, m, CH=CH_2), and 7·1—7·6 (15H, m, Ph) (Found: C, 75·5; H, 7·0. $C_{29}H_{32}O_5$ requires C, 75·65; H, 7·0%).

Proof of D-allo-*Configuration of the Alkene* (7).—The alkene (7) (40 mg) in aqueous acetic acid (75% v/v; 2 ml) was heated at 100° for 1 h. After evaporation, the residue was partitioned between water and chloroform, the aqueous layer evaporated to dryness, and the resulting syrup dissolved in ethanol (90%; 30 ml). The solution was cooled in ice and ozonised oxygen was bubbled through for 20 min. Water (1 ml) was added and the solvent removed *in vacuo*. The residue was examined by paper chromatography. Allose, and a small amount of ribose, were detected, by comparison with authentic D-allose, D-altrose, L-arabinose, D-lyxose, D-ribose, and D-xylose. The residual syrup was dissolved in water, sodium borohydride (50 mg) was added, and the mixture was kept at room temperature for 18 h. After addition of acetic acid, the solution was passed through a short column of Amberlite IR 120 resin (H^+ form) and the eluate evaporated to dryness. The boric acid was removed by evaporation with methanol (thrice) and the residue treated with ethanol. Slightly impure allitol, m.p. 136°, crystallised. Recrystallisation from ethanol afforded allitol, m.p. 146° (uncorr.), indistinguishable (i.r. spectrum, mixed m.p.) from an authentic sample.

2,3-O-*Isopropylidene*-5-O-*trityl*-α-D-*ribofuranosylethyne* (9).—The ethyne (4) (1·0 g) was added to a solution of toluene-*p*-sulphonyl chloride (1·5 g, 3·6 mol. equiv.) in dry pyridine (10 ml) and the mixture heated to 85—90° for 3·25 h. After hydrolysis of the excess of acid chloride with water the solution was evaporated to dryness. The product was isolated by means of chloroform and the resulting syrup chromatographed on silica gel (eluant benzene). The *ribosylethyne* (9) was obtained as a syrup which became a solid foam under high vacuum (868 mg, 90%), $[\alpha]_D$ −23·8° (*c* 0·41 in $CHCl_3$); $\nu_{max.}$ (KBr) 3290 (≡CH), 2130 (C≡C), 1390 and 1380 (both CMe_2), 3090, 3060, 3030, 1600, 1495, and 710 cm^{-1} (all Ph); δ (100 MHz; $CDCl_3$) 1·36 and 1·56 (6H, 2s, CMe_2), 2·62 (1H, d, *J* 2 Hz, ≡CH), 3·0—5·1 (6H, m), and 7·0—7·6 (15H, m, Ph) (Found: C, 79·05; H, 6·35. $C_{29}H_{28}O_4$ requires C, 79·1; H, 6·4%).

2,3-O-*Isopropylidene*-α-D-*ribofuranosylethyne* (10).—The trityl ether (9) (868 mg) was dissolved in ethanol (1 ml) and 50% aqueous acetic acid added. After 90 min at 100° solvents were removed by evaporation and the residue was

[29] S. M. Partridge, *Nature*, 1949, **164**, 443.
[30] F.E. Hardy and J. G. Buchanan, *J. Chem. Soc.*, 1963, 5881.
[31] E. R. H. Jones, L. Skatteböl, and M. C. Whiting, *J. Chem. Soc.*, 1956, 4765.
[32] H. Ohrui and J. J. Fox, *Tetrahedron Letters*, 1973, 1951.

partitioned between water and benzene. The cloudy aqueous layer was evaporated to dryness and treated with 2,2-dimethoxypropane (10 ml), acetone (50 ml), and toluene-*p*-sulphonic acid (50 mg) for 45 min at room temperature. The mixture was neutralised ($NaHCO_3$) and the product isolated using chloroform. The crude syrup was chromatographed on silica gel (15 g). Benzene–ether (9 : 1) eluted the pure *ribosylethyne* (10) as a syrup (302 mg, 77%) which slowly afforded hygroscopic crystals, m.p. 39·5—40·5° (uncorr.), $[\alpha]_D$ −48·3° (*c* 1·11 in $CHCl_3$); $\nu_{max.}$ (film) 3285 (≡CH), 2120 (C≡C), 3450 (OH), and 1385 and 1375 cm^{-1} (both CMe_2); δ (100 MHz; $CDCl_3$) 1·38 and 1·59 (6H, 2s, CMe_2), 2·20 (1H, s, exchangeable by D_2O, HO-5), 2·63 (1H, d, *J* 2 Hz, ≡CH), 3·55—3·85 (2H, m), 4·22 (1H, t), and 4·75—4·84 (3H, m) (Found: C, 60·1; H, 7·3. $C_{10}H_{14}O_4$ requires C, 60·6; H, 7·1%).

α-D-*Ribofuranosylethyne* (11).—The acetal (10) (300 mg) in methanol (20 ml) and water (5 ml) was heated under reflux, in the presence of Amberlite IR 120 resin (H^+ form) (0·5 g) for 3·5 h. After removal of the resin, evaporation gave a syrup (226 mg) which, on addition of ethyl acetate, gave crystals (168 mg). Recrystallisation from ethyl acetate yielded the pure *triol* (11) (141 mg, 59%), m.p. 102—102·5°; $[\alpha]_D$ +9·8° (*c* 2·04 in EtOH); $\nu_{max.}$ (KBr) 3265 (≡CH), 2120 (C≡C), 3460, 3360, and 3195 cm^{-1} (all OH); δ (100 MHz; [$^2H_5$]pyridine) 3·58 (1H, d, *J* 2 Hz, ≡CH), 4·3 (2H, m), 4·8 (2H, m), 5·3 (1H, dd, $J_{1,2}$ 4 Hz, H-1), 6·22br (4H, s); when D_2O was used as solvent, exchange of the acetylenic proton took place during the running of the spectrum (Found: C, 53·4; H, 6·4. $C_7H_{10}O_4$ requires C, 53·2; H, 6·3%).

2,3,5-*Tri*-O-*benzyl*-α-D-*ribofuranosylethyne* (12).[33]—The triol (11) (23 mg) was dissolved in a mixture of dry dimethylformamide (2 ml) and benzyl chloride (100 mg). Sodium hydride (50% oil suspension; 50 mg) was added, the mixture was kept at room temperature overnight, and solids were removed by filtration. The solution was evaporated and the residue was examined by t.l.c. [light petroleum–ether (1 : 1)]. The major product corresponded to the benzyl ether (12). The syrup was chromatographed on silica gel (3·5 g). Light petroleum–ether (1 : 1) eluted the benzyl ether (12), obtained as a pure syrup (41 mg, 66%) which crystallised immediately on nucleation. Recrystallised from aqueous ethanol it had m.p. 52—53° and was indistinguishable (mixed m.p., i.r., n.m.r., and t.l.c.) from the compound prepared previously.[1]

3-O-*Benzoyl*-1,2-*dideoxy*-4,5-O-*isopropylidene*-7-O-*trityl*-D-allo-*hept*-1-*ynitol* (13).—The diol (4) (950 mg) and benzoyl chloride (370 mg, 1·27 mol. equiv.) were added to dry pyridine (10 ml) and the mixture was kept overnight. After addition of a few drops of water the product was isolated by means of chloroform. The resulting syrup crystallised on addition of ether and light petroleum. Recrystallisation from ethanol gave the pure *monobenzoate* (13) (963 mg, 82%), m.p. 159—160°, $[\alpha]_D$ −13·4° (*c* 1·27 in $CHCl_3$); $\nu_{max.}$ (KBr) 3310 (≡CH), 2130 (C≡C), 1720 (C=O), 3570 (OH), 1375 (CMe_2), 3090, 3060, 3040, 1610, 1500, and 710 cm^{-1} (Ph); δ (100 MHz; $CDCl_3$) 1·38 and 1·46 (6H, 2s, CMe_2), 2·49 (1H, d, $J_{1,3}$ 2 Hz, H-1), 2·55 (1H, s, exchanges with D_2O, HO-6), 3·2—4·6 (5H, m), 6·03 (1H, dd, $J_{3,4}$ 4 Hz, H-3), and 7·0—8·2 (20H, m, Ph) (Found: C, 76·9; H, 6·3. $C_{36}H_{34}O_6$ requires C, 76·9; H, 6·05%).

3-O-*Benzoyl*-1,2-*dideoxy*-4,5-O-*isopropylidene*-6-O-*methylsulphonyl*-7-O-*trityl*-D-allo-*hept*-1-*ynitol* (14).—The benzoate (13) (240 mg) and methanesulphonyl chloride (120 mg, 2·5 mol. equiv.) in pyridine (5 ml) were kept at room temperature overnight. After addition of a few drops of water the product was isolated using chloroform. Recrystallised from ethanol the *sulphonate* (14) (245 mg, 90%) had m.p. 147—148°, $[\alpha]_D$ −9·2° (*c* 0·76 in $CHCl_3$); $\nu_{max.}$ (KBr) 3260 (≡CH), 2110 (C≡C), 1390 and 1380 (both CMe_2), 1730 (C=O), 1355, 1180 (SO_2), 3060, 3030, 1600, 1490, 720, and 710 cm^{-1} (Ph); δ (100 MHz; $CDCl_3$) 1·38 and 1·46 (6H, 2s, CMe_2), 2·47 (1H, d, $J_{1,3}$ 2 Hz, H-1), 2·93 (3H, s, SO_2Me), 3·5—5·3 (5H, m), 5·77 (1H, dd, $J_{3,4}$ 5 Hz, H-3), and 7·0—8·1 (20H, m, Ph) (Found: C, 69·2; H, 5·7. $C_{37}H_{36}O_8S$ requires C, 69·4; H, 5·6%).

3-O-*Benzoyl*-1,2-*dideoxy*-4,5-O-*isopropylidene*-6-O-*methylsulphonyl*-D-allo-*hept*-1-*ynitol* (15).—The sulphonate (14) (380 mg) was dissolved in chloroform (25 ml), and concentrated hydrochloric acid (10 drops from a fine capillary) was added. The mixture was stirred at room temperature for 1·5 h and then shaken with aqueous 10% sodium carbonate (5 ml). The chloroform layer was dried (Na_2SO_4) and evaporated to give a syrup which was chromatographed on silica gel (12 g). Light petroleum–ether (6 : 4) eluted the *alcohol* (15), which was obtained as a pure syrup (220 mg, 93%); $\nu_{max.}$ (film) 3290 (≡CH), 2130 (C≡C), 1735 (C=O), 1185 (SO_2), 3550 (OH), and 1395 cm^{-1} (CMe_2); δ (100 MHz; $CDCl_3$) 1·40 and 1·58 (6H, 2s, CMe_2), 2·38br (1H, s, HO-7), 2·60 (1H, d, $J_{1,3}$ 2 Hz, H-1), 3·19 (3H, s, SO_2Me), 3·8—5·3 (5H, m), 5·97 (1H, dd, $J_{3,4}$ 3 Hz, H-3), and 7·2—7·7 and 8·0—8·2 (5H, m, Ph) (Found: C, 53·9; H, 5·5. $C_{18}H_{22}O_8S$ requires C, 54·3; H, 5·6%).

3,6-*Di*-O-*benzoyl*-1,2-*dideoxy*-4,5-O-*isopropylidene*-7-O-*p*-*tolylsulphonyl*-D-allo-*hept*-1-*ynitol* (21).—The triol (3) (205 mg) and toluene-*p*-sulphonyl chloride (210 mg, 1·15 mol. equiv.) were dissolved in dry pyridine (2 ml). After 2·5 h the product was isolated using chloroform and treated with benzoyl chloride (300 mg) in pyridine (2 ml) for 18 h. The product was isolated by means of chloroform. Crystallisation from 90% ethanol afforded the pure *sulphonate* (21) (187 mg, 34%), m.p. 112—113°, $[\alpha]_D$ −9·2° (*c* 1·085 in $CHCl_3$); $\nu_{max.}$ (KBr) 3280 (≡CH), 2130 (C≡C), 1735 (C=O), 1180 (SO_2), 1390 and 1380 (both CMe_2), 3090, 3060, 3030, 1605, 1500, and 715 cm^{-1} (Ar); δ (100 MHz; $CDCl_3$) 1·48 and 1·54 (6H, 2s, CMe_2), 2·37 (3H, s, Me of Ts), 2·41 (1H, d, $J_{1,3}$ 2 Hz, H-1), 4·4—5·0 (4H, m), 6·4—6·6 (1H, m), 6·90 (1H, dd, $J_{3,4}$ 4 Hz, H-3), and 7·2—8·2 (14H, m, Ar) (Found: C, 64·8; H, 5·5; S, 5·8. $C_{31}H_{30}O_9S$ requires C, 64·4; H, 5·2; S, 5·5%).

2,3-O-*Isopropylidene*-5-O-*trityl*-α-L-*lyxofuranosylethyne* (17).—The sulphonate (14) (100 mg) was treated with sodium methoxide [from sodium (20 mg)] in methanol (5 ml) for 30 min. Solvent was removed *in vacuo* and the product isolated using chloroform. Methyl benzoate was removed from the syrup (70 mg) by evaporation in high vacuum. The residue crystallised from benzene–light petroleum to give the *lyxosylethyne* (17) (53 mg, 65%) as a benzene solvate, m.p. 67—68°, $[\alpha]_D$ +33·8° (*c* 0·36 in $CHCl_3$); $\nu_{max.}$ (KBr) 3305 (≡CH), 2120 (C≡C), 1390 and 1385 (both CMe_2), 3090, 3060, 3040, 1610, 1500, 720, and 705 cm^{-1} (Ph and C_6H_6); δ (100 MHz; $CDCl_3$) 1·27 and 1·29 (6H, 2s, CMe_2), 2·43 (1H, d, *J* 2 Hz, C≡CH), 3·3—4·8 (6H, m), and 7·0—7·6 (21H, m, Ph and C_6H_6) (Found: C, 80·9; H, 6·6. $C_{29}H_{28}O_4,C_6H_6$ requires C, 81·1; H, 6·6%).

2,3-O-*Isopropylidene*-α-L-*lyxofuranosylethyne* (18).—(*a*) The sulphonate (15) (120 mg) was treated with methanolic

[33] J. S. Brimacombe, B. D. Jones, M. Stacey, and J. J. Willard, *Carbohydrate Res.*, 1966, **2**, 167.

sodium methoxide (5·0 ml) [from sodium (15 mg)] for a few min at room temperature, and the solution was evaporated to dryness. The product was isolated using chloroform and the resulting syrup chromatographed on silica gel (10 g). Light petroleum–ether (7 : 3) eluted the ethyne (18) together with some methyl benzoate which was removed under high vacuum. The syrup (60 mg, 99%) was the pure *ethyne* (18); $\nu_{max.}$ (film) 3420 (OH), 3280 (≡CH), 2120 (C≡C), and 1395sh and 1385 cm^{-1} (both CMe_2); δ (100 MHz; $CDCl_3$) 1·31 and 1·38 (6H, 2s, CMe_2), 2·20br (1H, s, HO-5), 2·47 (1H, d, *J* 2 Hz, C≡CH), 3·7—4·2 (3H, m), and 4·7—4·9 (3H, m) (Found: C, 60·6; H, 7·0. $C_{10}H_{14}O_4$ requires C, 60·6; H, 7·1%). Tritylation by the usual procedure yielded the trityl ether (17), m.p. 63—64·5° (uncorr.) (from benzene–light petroleum), indistinguishable from an authentic sample (i.r., t.l.c.).

(*b*) The sulphonate (21) (225 mg) was dissolved in methanolic sodium methoxide [30 ml; from sodium (30 mg)]. After 1 h at room temperature t.l.c. [light petroleum–ether (1 : 1)] indicated the presence of one major and two very minor products. The product was isolated using chloroform and chromatographed on silica gel (12 g). Light petroleum–ether (6 : 4) eluted the ethyne (18) as a pure syrup (51 mg, 66%) which slowly crystallised. Recrystallised from ether–light petroleum it had m.p. 60·5—61°, $[\alpha]_D$ +25·1° (*c* 0·345 in $CHCl_3$), whose n.m.r. spectrum (100 MHz; $CDCl_3$) was identical with that in (*a*), except that the HO-5 signal appeared as a triplet, δ 2·23. Tritylation afforded the trityl ether (17), m.p. 67—68°, identical (t.l.c., i.r.) with an authentic sample.

1,2-*Dideoxy*-6,7-O-*carbonyl*-4,5-O-*isopropylidene*-D-allo-*hept*-1-*ynitol* (23).—The triol (3) (250 mg) was dissolved in dry pyridine (2·5 ml); the solution was cooled to 0 °C and treated with a solution of phosgene in toluene [0·9 g; 12·5% (w/w)]. After 72 h at room temperature, more phosgene solution (0·8 g) was added and the mixture kept for 24 h. The excess of reagent was destroyed with water and the product isolated with chloroform. The resulting syrup was chromatographed on silica gel (9 g). Elution with light petroleum–ether (6 : 4) afforded the *carbonate* (23), (175 mg, 62%), m.p. 116—117° (from benzene–light petroleum); $\nu_{max.}$ (KBr) 3295 (≡CH), 2130 (C≡C), 1775 (C=O), 3450 (OH), and 1405 and 1390 cm^{-1} (both CMe_2); δ (100 MHz; $CDCl_3$) 1·40 and 1·52 (6H, 2s, CMe_2), 2·59 (1H, d, $J_{1,3}$ 2 Hz, H-1), 2·71 (1H, d, *J* 4 Hz, exchangeable by D_2O, HO-3), 4·2—4·8 (5H, m), and 5·26 (1H, dt, H-6) (Found: C, 54·4; H, 5·8. $C_{11}H_{14}O_6$ requires C, 54·5; H, 5·8%).

1,2-*Dideoxy*-6,7-O-*carbonyl*-4,5-O-*isopropylidene*-3-O-*p*-*tolylsulphonyl*-D-allo-*hept*-1-*ynitol* (24).—The carbonate (23) (115 mg) and toluene-*p*-sulphonyl chloride (250 mg) were dissolved in dry pyridine (1 ml) and the solution warmed to 90° for 75 min. After 24 h at room temperature the product was isolated by means of chloroform and purified by chromatography on silica gel (3 g) (ether as eluant). Crystallisation of the major product from chloroform–light petroleum gave the *sulphonate* (24) (70 mg, 37%), m.p. 129—130° (uncorr.); $\nu_{max.}$ (KBr) 3295 (≡CH), 2135 (C≡C), 1810 (C=O), 1190 (SO_2), 1395 and 1380 (both CMe_2), 3080, 3060, 3040, 1610, 1505, and 820 cm^{-1} (Ar); δ (100 MHz; $CDCl_3$) 1·36 and 1·44 (6H, 2s, CMe_2), 2·45 (3H, s, Me of Ts), 2·57 (1H, d, $J_{1,3}$ 2 Hz, H-1), 4·3—4·6 (4H, m), 5·0—5·4 (2H, m), 7·30, 7·39, 7·77, and 7·86 (4H, dd, Ar) (Found: C, 54·4; H, 5·0. $C_{18}H_{20}O_8S$ requires C, 54·55; H, 5·05%).

(E)-1,2,3-*Trideoxy*-6,7-O-*carbonyl*-4,5-O-*isopropylidene*-D-erythro-*hept*-1-*yn*-3-*enitol* (25).—The sulphonate (24) (75 mg) was heated in dry dimethylformamide (2 ml) with sodium benzoate (200 mg) for 2 h at 125°. The solvent was evaporated off and the product isolated by means of chloroform. Chromatography on silica gel (5 g) and elution with light petroleum–ether (7 : 3) yielded a crystalline solid which was recrystallised from ether–light petroleum to give the pure *enol ether* (25) (19 mg, 45%), m.p. 110° (decomp.), $\lambda_{max.}$ (EtOH) 238 nm; $\nu_{max.}$ (KBr) 3280 (≡CH), 2110 (C≡C), 1670 (C=CO), 1810, 1785 (both C=O), and 1405 and 1395 cm^{-1} (both CMe_2); δ (100 MHz; $CDCl_3$) 1·44 and 1·59 (6H, 2s, CMe_2), 3·08 (1H, d, $J_{1,3}$ 2·5 Hz, H-1), 4·22 (1H, dd, $J_{6,7}$ 5·0 Hz, $J_{7,7'}$ 8·75 Hz, H-7), 4·46 (1H, t, $J_{6,7'}$ 8·25 Hz, H-7'), 5·05 (1H, t, $J_{3,5}$ 2·5 Hz, H-3), 5·25 (1H, t, $J_{5,6}$ 2·5 Hz, H-5), and 5·54 (1H, ddd, H-6); *m/e* 224 (M^+).

Oxidation of 1,2-*Dideoxy*-4,5-O-*isopropylidene*-D-allo-*hept*-1-*ynitol* (3).—(a) *With manganese dioxide*. The triol (3) (370 mg) was dissolved in acetone (30 ml), freshly ground manganese dioxide [21] (5 g) was added, and the suspension was stirred at room temperature. After 75 min, t.l.c. indicated that only a trace of triol remained. The manganese dioxide was filtered off and washed with acetone, and the combined filtrate was evaporated to a syrup, which, after removal of insoluble inorganic matter, was chromatographed on silica gel (15 g). Light petroleum–ether (7 : 3) eluted two main fractions: a syrup (B) consisting of less polar material (131 mg) and containing a major component whose further purification is described below; and a homogeneous syrup (C) (148 mg) which crystallised from chloroform–light petroleum to give 1,2-*dideoxy*-D-ribo-*hept*-1-*yn*-3-*ulofuranose* (29b) (90 mg, 25%), m.p. 120—121°, $[\alpha]_D$ −82·7° (2 min) (*c* 0·52 in EtOH); $\nu_{max.}$ (KBr) 3260 (≡CH), 2120 (C≡C), 3400 (OH), and 1390 and 1375 cm^{-1} (both CMe_2); δ (100 MHz; [$^2H_6$]acetone) 1·37 and 1·52 (6H, 2s, CMe_2), 3·26 (1H, s, H-1), 3·8—4·0 (2H, m), 4·2—5·3 (4H, m), and 6·1—6·8br (1H, s, OH) (Found: C, 56·2; H, 6·3. $C_{10}H_{14}O_5$ requires C, 56·1; H, 6·5%).

The syrup (B) (245 mg) was chromatographed on silica gel (15 g). Benzene–ether (9 : 1) eluted a pure fraction which on evaporation yielded a syrup (146 mg). Crystallisation from ether–light petroleum afforded 5,6-*dideoxy*-2,3-O-*isopropylidene*-L-ribo-*hex*-5-*ynofuranose* (31b) (116 mg, 37%), m.p. 74—75°, $[\alpha]_D$ +10·7° (2 min) (*c* 0·84 in EtOH); $\nu_{max.}$ (KBr) 3260 (≡CH), 2120 (C≡C), 3390 (OH), and 1390 and 1380 cm^{-1} (both CMe_2); δ (100 MHz; $CDCl_3$) 1·31 and 1·46 (6H, 2s, CMe_2), 2·61 (1H, d, $J_{4,6}$ 2 Hz, H-6), 3·30 (1H, d, *J* 3 Hz, exchangeable in D_2O, HO-1), 4·60—5·10 (3H, m), and 5·50 (1H, d, $J_{1,2}$ 3 Hz, H-1) (Found: C, 58·6; H, 6·6. $C_9H_{12}O_4$ requires C, 58·7; H, 6·5%).

(b) *With sodium periodate*. The triol (3) (240 mg) was dissolved in water (5 ml) together with sodium hydrogen carbonate (100 mg) and sodium periodate (290 mg). After 15 min the solution was extracted twice with chloroform (50 ml). The combined extracts were dried (Na_2SO_4) and evaporated to leave a chromatographically homogeneous syrup (166 mg, 81%), which crystallised from ether–light petroleum to give the furanose (31b), m.p. 74—75°, indistinguishable (mixed m.p., i.r., and t.l.c.) from the compound in (a).

Reaction of 2,3-O-*Isopropylidene*-D-*ribono*-1,4-*lactone* (28) *with Ethynylmagnesium Bromide*.—To a solution of the lactone (28) (3·621 g) in dry tetrahydrofuran (20 ml) was added, dropwise, a solution of ethynylmagnesium bromide

(2·16 mol. equiv.) in tetrahydrofuran (80 ml) prepared as before.[31] After 20 h at room temperature, aqueous 10% ammonium chloride (10 ml) was added and the mixture stirred for a further 30 min. The organic layer was separated and the aqueous layer extracted thrice with ethyl acetate (50 ml). The combined extracts were dried (Na_2SO_4) and evaporated to give a syrup (4·23 g) which was decolourised by filtration of a solution in light petroleum–ether (1 : 1) through a short column of silica gel. The resulting syrup (3·74 g) yielded crystals (1·05 g) shown (i.r. spectrum) to be a mixture of the lactone (28) and the ketose (29b). The remaining syrup (2·65 g) was chromatographed on silica gel (40 g). Benzene–ether (7 : 3) eluted more of the crystalline mixture (D) (1·65 g; total 2·70 g), followed by a second fraction (480 mg) which crystallised from benzene–light petroleum to give 1,2-*dideoxy*-3-C-*ethynyl*-4,5-O-*isopropylidene*-D-ribo-*hept*-1-*ynitol* (30) (314 mg, 7%), m.p. 123—124°, $[\alpha]_D$ −74·4° (*c* 1·09 in $CHCl_3$); $\nu_{max.}$ (KBr) 3480, 3410, and 3150 (all OH). 3290 (≡CH), 2120 (C≡C), and 1390 and 1385 cm^{-1} (both CMe_2); δ (100 MHz; [$^2H_5$]pyridine) 1·40 and 1·72 (6H, 2s, CMe_2), 3·49 and 3·53 (2H, 2s, both ≡CH), 4·0—4·6 (2H, m), 4·7—5·0 (2H, m), 5·1—5·4 (1H, m), and 5·9—6·3, 6·4—7·0, and 9·6—10·2 (3H, 3 br s, all OH) (Found: C, 59·7; H, 6·8. $C_{12}H_{16}O_5$ requires C, 60·0; H, 6·7%).

2,3-O-*Isopropylidene*-5-O-*trityl*-β-D-*ribofuranosylethyne* (20).—(*a*) The trityl ether (4) (750 mg) was dissolved in benzene (85 ml) and freshly ground active manganese dioxide [21] (8 g) was added. The mixture was stirred at room temperature for 70 min and filtered; the filtrate was evaporated to yield the crude ketose (34) as a thick syrup (720 mg, 96%) which gave one major spot, of higher R_F value than the trityl ether (4), on t.l.c. [light petroleum–ether (1 : 1)]. The syrup was dissolved in ethanol (35 ml) and sodium borohydride (132 mg) added. After 20 h at room temperature, t.l.c. indicated a product of R_F similar to that of the *allo*-diol (4) together with minor products of lower R_F value. When the solvent had been removed the mixture [(4) and (6)] was isolated using chloroform to yield a solid foam (660 mg, 91%).

The crude mixture of diols [(4) and (6)] (300 mg) was dissolved in dry pyridine (5 ml), toluene-*p*-sulphonyl chloride (500 mg) was added, and the solution was heated at 80 °C for 4 h. A further quantity (100 mg) of toluene-*p*-sulphonyl chloride was added and heating continued for 1 h. After addition of a little water the mixture was set aside overnight. The product was isolated by means of chloroform and the resulting syrup chromatographed on silica gel (12 g). Light petroleum–ether (9 : 1) eluted the following pure fractions.

(i) The β-D-*ribosylethyne* (20) as a syrup (82 mg, 28%), $[\alpha]_D$ −18·9° (*c* 0·265 in $CHCl_3$); $\nu_{max.}$ (film) 3290 (≡CH), 2120 (C≡C), 1390 and 1380 (both CMe_2), 3090, 3060, 3035, 1605, 1500, 770, and 710 cm^{-1} (Ph); δ (100 MHz; $CDCl_3$) 1·36 and 1·56 (6H, 2s, CMe_2), 2·40 (1H, d, *J* 2 Hz, ≡CH), 3·34 (2H, m), 4·1—5·0 (4H, m), and 7·1—7·9 (15H, m, Ph) (Found: C, 78·8; H, 6·5. $C_{29}H_{28}O_4$ requires C, 79·1; H, 6·4%).

The trityl ether (20) (100 mg) was heated for 1 h in 50% aqueous acetic acid (5 ml) and the mixture then evaporated to dryness. The residue was dissolved in acetone (20 ml) containing a drop of concentrated sulphuric acid and set aside for 18 h. The mixture was neutralised ($NaHCO_3$ solution), the solvent was removed *in vacuo*, and the residue was chromatographed on silica gel. Light petroleum–ether (4 : 1) eluted an isopropylidene compound, presumably (19) (32 mg, 71%), which was dissolved in methanol (5 ml) and heated under reflux in the presence of Amberlite IR 120 resin (H^+ form) ion-exchange resin (0·5 g) for 3 h. After removal of resin (filtration) and solvent (evaporation) the β-D-ribosylethyne (32) remained as a syrup (21 mg, 84%) which was dissolved in dimethylformamide (3 ml). To the solution benzyl chloride (150 mg) and sodium hydride (50—60% suspension in oil; 50 mg) were added.[33] After 24 h at room temperature the mixture was filtered, xylene (20 ml) was added and the solvents were evaporated off. T.l.c. [light petroleum–ether (1 : 1)] showed one major spot corresponding to the tribenzyl ether (33). The syrup was chromatographed on silica gel (4 g). Light petroleum–ether (7 : 3) eluted the tribenzyl ether (33) as a pure syrup (26 mg, 46%) which rapidly crystallised on nucleation. After recrystallisation from aqueous ethanol it had m.p. 63° and was indistinguishable (mixed m.p., i.r., t.l.c.) from an authentic sample.[1]

(ii) The α-D-ribosylethyne (9) (39 mg, 14%), identified by comparison (i.r., t.l.c.) with an authentic sample.

(iii) 2,3-O-*Isopropylidene*-5-O-*trityl*-β-L-*lyxofuranosylethyne* (35) as a syrup (41 mg, 14%); $\nu_{max.}$ (film) 3290 (≡CH), 2130 (C≡C), 1385 and 1375 (both CMe_2), 3090, 3060, 3030, 1600, 1495, and 705 cm^{-1} (Ph); δ (60 MHz; $CDCl_3$) 1·33 and 1·38 (6H, 2s, CMe_2), 2·56 (1H, d, *J* 2 Hz, ≡CH), 3·1—3·9 (3H, m), 3·95—4·40 (1H, m), 4·6—4·8 (2H, m), and 7·1—7·9 (15H, m, Ph).

The trityl ether (35) (36 mg) was heated under reflux with Amberlite IR 120 resin (H^+) (1 g) in methanol (15 ml) for 4 h. The resin was filtered off and the methanol removed by evaporation. The residue was dissolved in acetone (15 ml) containing a trace of sulphuric acid and kept for 18 h. The solution was neutralised (NH_3) and evaporated and the residue was chromatographed on silica gel (4 g). Light petroleum–ether (7 : 3) eluted the acetal (36) (10 mg), which was further purified by distillation (95—100° and 10^{-1} mmHg) to give crystalline 2,3-O-*isopropylidene*-β-L-*lyxofuranosylethyne* (36), m.p. 107—108°, $[\alpha]_D$ −49·4° (*c* 0·81 in $CHCl_3$). The i.r. spectrum was indistinguishable from that of the D-isomer,[2] m.p. 107—108·5°, $[\alpha]_D$ +51·3° ($CHCl_3$); the specific rotation given in ref. 2 is incorrect.

(*b*) The crystalline mixture (D) of lactone (28) and ketose (29b) from the Grignard reaction above (930 mg) was dissolved in ethanol (10 ml) and treated with sodium borohydride (500 mg) for 16 h at room temperature. After acidification the product was isolated by means of ethyl acetate to give a syrup (920 mg) which was chromatographed on silica gel (15 g). Benzene–ether (4 : 6) eluted a chromatographically homogeneous mixture of triols [(3) and (5)] (450 mg) which did not crystallise.

The syrupy mixture (350 mg) was treated with trityl chloride (630 mg, 1·4 mol. equiv.) for 66 h at room temperature. The product was isolated using chloroform purified by chromatography as for the trityl ether (4). The resulting syrup (452 mg, 61%) was heated with toluene-*p*-sulphonyl chloride (1·25 g) in pyridine (5 ml) at 85 °C for 3 h. More acid chloride (250 mg) was added and heating was continued for 1·5 h. After hydrolysis of the excess of reagent the products were isolated using chloroform, giving a syrup (488 mg) which was chromatographed on silica gel. Light petroleum–benzene (1 : 1) eluted the pure trityl ether (20) (153 mg), followed by the other components (196 mg) as a mixture.

The trityl ether (20) (130 mg) was hydrolysed with 70%

aqueous acetic acid (3 ml) for 50 min at 100°. The solution was evaporated and the residue chromatographed on silica gel. Triphenylmethanol was eluted by benzene–ether; ethyl acetate eluted the triol (32) (34 mg, 72%), 32 mg of which was converted into the tribenzyl ether (33) (43 mg, 50%) with benzyl chloride and sodium hydride in dimethylformamide.[33] It had m.p. 63° and was indistinguishable from an authentic sample [1] (mixed m.p., i.r., t.l.c.) and from the compound in (*a*) (i) above.

(*c*) The syrup (A) (1·84 g), from the reaction of the sugar (1) with ethynylmagnesium bromide, was dissolved in pyridine (10 ml), trityl chloride (2·0 g) was added, and the mixture was kept for 2 days at room temperature. It was then heated to 80—85 °C for 5 h, ethanol (50 ml) was added, and solvents were removed *in vacuo*. The product was isolated by means of chloroform, and the resulting syrup chromatographed on silica gel (30 g). Light petroleum–ether (7 : 3) eluted the syrupy mixture of diols [(4) and (6)] (1·118 g), having identical R_F values on t.l.c. The syrup was dissolved in pyridine (10 ml), toluene-*p*-sulphonyl chloride (1·5 g) was added, and the mixture was heated to 85—90 °C for 6 h. After hydrolysis of the excess of reagent the product was isolated using chloroform. The resulting brown syrup (1·09 g) was chromatographed on silica gel (20 g) (elution with benzene). After rechromatography of mixed fractions, the β-D-ribosylethyne (20) [95 mg, 0·8% from the acetal (1)] and the α-D-ribosylethyne (9) (794 mg, 7%) were each obtained in a pure state. The β-D-ribosyl ethyne was identified by comparison of its n.m.r. spectrum with that of the compound prepared in (*a*) (i) above.

We thank Dr. N. A. Hughes and Dr. B. E. Stacey for samples of reference compounds and the S.R.C. for a research studentship (to A. D. D.) and for n.m.r. spectra measured at the P.C.M.U., Harwell.

[4/2446 *Received*, 22*nd November*, 1974]