Synthesis of *C*-Glycosyl Compounds. Part 1.[1] Reaction of Ethyl Isocyanoacetate with 2,3:5,6-Di-*O*-isopropylidene-D-mannono-1,4-lactone

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Formylaminomethylenation of 2,3:5,6-di-*O*-isopropylidene-D-mannono-1,4-lactone (1) with ethyl isocyanoacetate (2) gave, as the major product, (*E*)-ethyl 3,6-anhydro-2-deoxy-2-formylamino-4,5:7,8-di-*O*-isopropylidene-D-*manno*-oct-2-enonate (3) (58%), which on hydrogenation gave ethyl 3,6-anhydro-2-deoxy-2-formylamino-4,5:7,8-di-*O*-isopropylidene-D-*erythro*-L-*gluco*-octonate (17), in almost quantitative yield. Base-catalysed equilibration of the D-*erythro*-L-*gluco*-octonate (17) gave a mixture of the L-*allo*-, L-*altro*-, L-*gluco*-, and L-*manno*-epimers [(23), (22), (17), and (19), respectively]. The configurations at C-2 and C-3 of these epimers were established by chemical and physical methods.

The D-*erythro*-L-*gluco*-epimer (17) and the D-*erythro*-L-*manno*-epimer (19) were degraded to ethyl 3,6-anhydro-2-deoxy-2-formylamino-4,5-*O*-isopropylidene-D-*glycero*-L-*gluco*-heptonate (37) and its D-*glycero*-L-*manno*-epimer (39), respectively. Acidic hydrolysis of compounds (17), (19), (37), and (39) gave the free amino-acids, L-2-(β-D-mannofuranosyl)-glycine (41), the analogous D-amino-acid (42), L-2-(β-D-lyxofuranosyl)-glycine (43), and the analogous D-amino-acid (44), in moderate yields.

In the presence of base, alcohols and thiols readily attacked the double bond of the oct-2-enonate (3) to give, for example, ethyl (ethyl 2-deoxy-2-formylamino-4,5:7,8-di-*O*-isopropylidene-α-D-*manno*-D-*glycero*-oct-3-ulo-3,6-furanosid)onate and its D-*manno*-L-*glycero*-epimer [(9) and (10)].

THE discovery of the naturally occurring *C*-nucleosides [2] and polyoxins [3] has led to interest in *C*-glycosyl compounds [4,5] and carbon–carbon-linked sugar α-amino-acids.[6] We report a method for the introduction of a carbon–carbon linkage at C-1 of an aldonic acid lactone, leading to *C*-glycosyl compounds, and its use in the synthesis of glycosyl α-amino-acids.

Carbon–carbon double bonds can be formed by treating α-metallated isocyanides with aldehydes and ketones in an aprotic solvent (formylaminomethylenation [7]) but attempts [8] to effect reactions of lithiated ethyl isocyanoacetate with a series of esters (RCO_2Et; R = alkyl, Ph, EtO, or Me_2N) were unsuccessful. However, ethyl 5-isocyanomethyloxazole-4-carboxylate (7), the self-condensation product of ethyl isocyanoacetate (2), was obtained from these reactions, indicating that reaction with suitably activated esters can take place. The reaction with lactones has not been reported and an attempt, in these laboratories, to react potassiated ethyl isocyanoacetate (5) with γ-butyrolactone in tetrahydrofuran gave an intractable mixture. However, the reaction with 2,3:5,6-di-*O*-isopropylidene-D-mannono-1,4-lactone (1) gave the formylaminomethylenation products, (*E*)-ethyl 3,6-anhydro-2-deoxy-2-formylamino-4,5:7,8-di-*O*-isopropylidene-D-*manno*-oct-2-enonate (3) and its *Z*-isomer (4) in 58 and 5% yield, respectively.

Although the n.m.r. spectra of the oct-2-enonates (3) and (4) (and many of their derivatives) were complicated by the partial double-bond character of the amide [C(O)–N] bond,[9] they were readily characterised from their physical and analytical data. The stereochemistry

[1] Preliminary publication, K. Bischofberger, R. H. Hall, and A. Jordaan, *J.C.S. Chem. Comm.*, 1975, 806.

[2] R. J. Suhadolnik, 'Nucleoside Antibiotics,' Wiley-Interscience, New York, 1970, pp. 354, 390, and 393.

[3] See ref. 2, p. 218.

[4] L. Goodman in 'Basic Principles in Nucleic Acid Chemistry,' ed. P. O. P. Ts'O, Academic Press, New York, 1974, p. 117.

[5] For recent examples, see G. Just and S. Kim, *Tetrahedron Letters*, 1976, 1063; S. De Bernardo and M. Weigele, *J. Org. Chem.*, 1976, **41**, 287; F. G. De Las Heras, C. K. Chu, S. Y-K. Tam, R. S. Klein, K. A. Watanabe, and J. J. Fox, *J. Heterocyclic Chem.*, 1976, **13**, 175; J. G. Buchanan, A. R. Edgar, M. J. Power, and G. C. Williams, *Carbohydrate Res.*, 1975, **45**, 312; G. Trummlitz, D. B. Repke, and J. G. Moffatt, *J. Org. Chem.*, 1975, **40**, 3352; T. Huynh-Dinh, A. Kolb, C. Gouyette, J. Igolen, and S. Tran-Dinh, *ibid.*, p. 2825.

[6] N. P. Damodaran, G. H. Jones, and J. G. Moffatt, *J. Amer. Chem. Soc.*, 1971, **93**, 3812; T. Naka, T. Hashizume, and M. Nishimura, *Tetrahedron Letters*, 1971, 95; H. Ohrui, H. Kuzuhara, and S. Emoto, *ibid.*, p. 4267; S. Ohdan, T. Okamoto, S. Maeda, T. Ichikawa, Y. Araki, and Y. Ishido, *Bull. Chem. Soc. Japan*, 1973, **46**, 981; H. Paulsen and E. Mäckel, *Chem. Ber.*, 1973, **106**, 1525; K. Ochi and K. Okui, *Chem. and Pharm. Bull. (Japan)*, 1974, **22**, 2223; A. J. Brink, J. Coetzer, O. G. de Villiers, R. H. Hall, A. Jordaan, and G. J. Kruger, *Tetrahedron*, 1976, **32**, 965, and earlier papers; A. Rosenthal and A. J. Brink, *J. Carbohydrates Nucleosides Nucleotides*, 1976, **2**, 343; *Carbohydrate Res.*, 1976, **47**, 332.

[7] D. Hoppe, *Angew. Chem. Internat. Edn.*, 1974, **13**, 789; U. Schöllkopf, *ibid.*, 1970, **9**, 763.

[8] R. Schröder, U. Schöllkopf, E. Blume, and I. Hoppe, *Annalen*, 1975, 533.

[9] A. J. Brink and A. Jordaan, *Carbohydrate Res.*, 1974, **34**, 1.

around the double bond of the (*E*)-oct-2-enonate (3) was deduced from the stereochemistry of derivatives of its hydrogenated products, the octonates (17) and (19) (see later).

A mixture of octulosonates (9) and (10) (1%) and a mixture of oxazole derivatives (8) (8%) were isolated as by-products of the reaction of the lactone (1) with ethyl isocyanoacetate. The octulosonates (9) and (10) were readily identified by comparison with authentic materials (see later). The n.m.r. spectrum of the mixture of oxazole derivatives (8) was similar to that of a mixture of the oct-2-enonates (3) and (4), but with two extra low-field singlets (τ 2.19 and 2.24), which indicated [8] the presence of the oxazole ring. The structures (8) were confirmed by i.r. and mass spectral and analytical data.

The by-products (8)—(10) must arise *via* the self-condensation reaction [8] of ethyl isocyanoacetate (2) which accompanies the main reaction. The reaction of potassiated ethyl isocyanoacetate (5) with unchanged reagent (2) gives the α-metallated isocyanide (6) which formylaminomethylenates the lactone (1) to give, after hydrolysis, a mixture of the oxazole derivatives (8). Ethanol is produced during the self-condensation reaction and, in the presence of the base, it reacts with the oct-2-enonates (3) and (4) to give the octulosonates (9) and (10) (see later).

The reactions of α-(formylamino)acrylic esters have been studied in considerable detail.[7] However, the unsaturated system of oct-2-enonates (3) and (4), $R^1(R^2O)C{=}C(NHCOR^3)CO_2R^4$, has not been described previously and, although our main interest in these compounds was their application to *C*-glycosyl synthesis, it was of added interest to investigate some reactions of the unsaturated system.

Irradiation of a 0.1M-solution of the (*E*)-oct-2-enonate (3) with unfiltered radiation for 1 h in nitrogen-purged benzene–acetone (4 : 1) gave a mixture of the *E*- and *Z*-isomers [*ca.* 15% (*Z*)-oct-2-enonate (4), as shown by the n.m.r. spectrum]. Further irradiation did not change the ratio of isomers, and the low conversion factor made the method unattractive as a preparative route to the (*Z*)-oct-2-enonate (4).

The (*E*)-oct-2-enonate (3) was converted [10] into its isocyano-analogue (11) with phosgene and triethylamine, making this compound available for synthetic operations such as those described [7,10] for similar compounds. The oxazole derivatives (8) were converted into the isocyano-analogues (12) in a similar way.

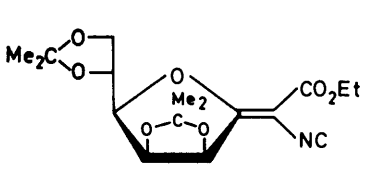
Hydrolysis of the (*E*)-oct-2-enonate (3) with dilute mineral acid (4 h; 100 °C) left the stabilized enamine moiety intact, to some extent, as the acetylated enamine (13) was isolated after treatment of the products of hydrolysis with acetic anhydride in pyridine.

An attempt to degrade the (*E*)-oct-2-enonate (3) to

[10] U. Schöllkopf, R. Harms, and D. Hoppe, *Annalen*, 1973, 611.

(*E*)-ethyl 3,6-anhydro-2-deoxy-2-formylamino-4,5-*O*-isopropylidene-D-*lyxo*-hept-2-enonate was unsuccessful. Selective removal of the 7,8-*O*-isopropylidene group by acidic hydrolysis gave the diol (14) [characterized as its di-*O*-acetate (15)] and the action of sodium periodate on the diol (14) gave the aldehyde (16), which could not be selectively reduced by catalytic hydrogenation or with equivalent amounts of sodium borohydride, sodium triacetoxyborohydride,[11] or lithium tri-t-butoxyaluminium hydride. In all cases intractable mixtures were obtained.

The (*E*)-oct-2-enonate (3) was hydrogenated over Raney nickel in ethanol (25 °C; 50 lb in^{-2}; 2—4 days) to give the D-*erythro*-L-*gluco*-octonate (17) (90%) and a trace of the D-*erythro*-L-*manno*-octonate (19). Attempts



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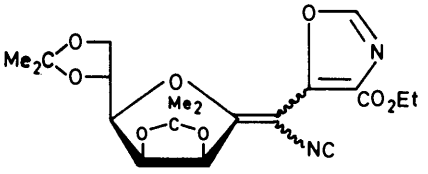
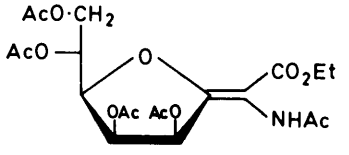


(12)



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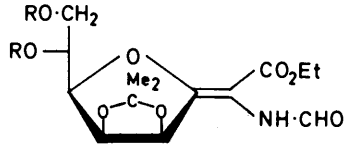
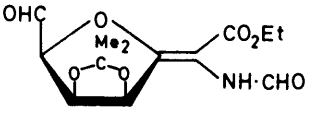


(14) R=H

(15) R=Ac



(16)

to hydrogenate the (*Z*)-oct-2-enonate (4) under the same conditions failed, and variation of the catalyst, solvent, pressure, and reaction time had no effect.

As amino-acids and their derivatives are susceptible to base-catalysed racemisation, it was considered that the D-*erythro*-L-*manno*-octonate (19) was formed through racemisation of the D-*erythro*-L-*gluco*-octonate (17) by traces of base present in the Raney nickel. The D-*erythro*-L-*gluco*-octonate (17) was recovered unchanged from a solution in pyridine after 24 h. However, after 1 week in ethanol containing a trace of sodium ethoxide, the D-*erythro*-L-*gluco*-octonate (17) was converted into a mixture containing not only the D-*erythro*-L-*gluco*- and the D-*erythro*-L-*manno*-octonates, (17) and (19), respectively, but also the D-*erythro*-L-*altro*- and the D-*erythro*-L-*allo*-octonates, (22) and (23), respectively. Column chromatography afforded the pure D-*erythro*-L-*gluco*- and the D-*erythro*-L-*manno*-octonates, but the D-*erythro*-L-*altro*- and the D-*erythro*-L-*allo*-octonates could not be separated from each other. Clearly, base-catalysed ' anomerisation ' [12] had taken place, together with racemisation of the amino-acid moiety. The four epimers were produced in approximately equal amounts and the ratio of ' α-anomeric ' to ' β-anomeric ' products (1 : 1) contrasts with that found (1 : 5) after base-equilibration [12c] of ethyl 3,6-anhydro-2-deoxy-2-ethoxycarbonyl-4,5:7,8-di-*O*-isopropylidene-D-*glycero*-D-*talo*-octonate (24) and its D-*glycero*-D-*galacto*-epimer (21).

As has been shown [9] for similar compounds, the ester group and the formylamino-group of the octonates (17), (19), (22), and (23) could be reduced selectively. Reduction of the D-*erythro*-L-*gluco*-octonate (17) with diborane [13] gave the methylamino-ester (18), and with either an excess of sodium borohydride or slightly more than 1 equiv. of lithium aluminium hydride, the formamido-alcohol (25) was formed. A large excess of lithium aluminium hydride gave the methylamino-alcohol (26). The methylamino-ester (20) and the formylamino-alcohol (27) were prepared similarly from the D-*erythro*-L-*manno*-octonate (19), and reduction of the mixture of the D-*erythro*-L-*altro*- and D-*erythro*-L-*allo*-octonates, (22) and (23), with a large excess of lithium aluminium hydride gave a mixture of the formylamino-alcohols (28).

These reduction products were used to determine the configuration at C-2 and -3 of the octonates (17), (19), (22), and (23), and their derivatives. It has been reported [12a,c] that the epimers (21) and (24) have $J_{3,4}$ values of *ca.* 3 and 0 Hz, respectively, and it was concluded that they were the 3*S*- and the 3*R*-epimer, respectively. The heptonates (37) and (39), prepared from the octonates (17) and (19), respectively (see later) have $J_{3,4}$ values of 3.5 and 3 Hz, respectively, indicating that the octonates (17) and (19), and their derivatives have the 3*S*-configuration. Correspondingly, the octonates (22) and (23) and their derivatives have the 3*R*-configuration.

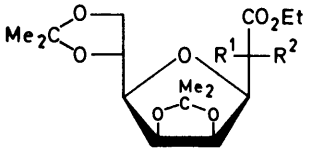
However, to establish unequivocally the configuration

[11] G. W. Gribble and D. C. Ferguson, *J.C.S. Chem. Comm.*, 1975, 535.

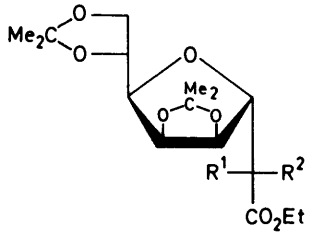
[12] (*a*) S. Hanessian and A. G. Pernet, *Canad. J. Chem.*, 1974, **52**, 1266; (*b*) H. Ohrui and J. J. Fox, *Tetrahedron Letters*, 1973, 1951; (*c*) H. Ohrui, G. H. Jones, J. G. Moffatt, M. L. Maddox, A. T. Christensen, and S. K. Bryan, *J. Amer. Chem. Soc.*, 1975, **97**, 4602.

[13] K. M. Biswas and A. H. Jackson, *J. Chem. Soc.* (*C*), 1970, 1667.

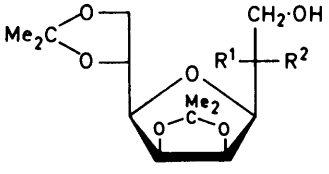
at C-3 of the octonates (17), (19), (22), and (23), and their derivatives, the 7,8-*O*-isopropylidene group of the methylamino-alcohol (26), derived from the D-*erythro*-L-*gluco*-octonate (17), was selectively removed by hydrolysis, to give the octitol (29). Treatment of the octitol (29) with sodium periodate gave the dialdehyde (30),



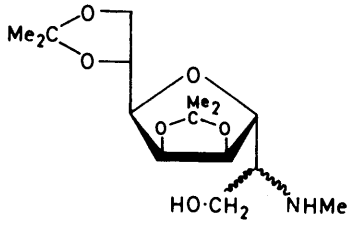
(17) R^1 = NH·CHO, R^2 = H
(18) R^1 = NHMe, R^2 = H
(19) R^1 = H, R^2 = NH·CHO
(20) R^1 = H, R^2 = NHMe
(21) R^1 = H, R^2 = CO_2Et



(22) R^1 = NH·CHO, R^2 = H
(23) R^1 = H, R^2 = NH·CHO
(24) R^1 = H, R^2 = CO_2Et

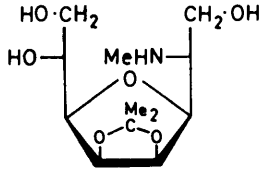


(25) R^1 = NH·CHO, R^2 = H
(26) R^1 = NHMe, R^2 = H
(27) R^1 = H, R^2 = NHMe



(28)

which was reduced with sodium borohydride to give the anhydro-hexitol (31). Acetylation with acetic anhydride gave 1,6-di-*O*-acetyl-2,5-anhydro-3,4-*O*-isopropylidene-D-galactitol (32). The ^1H and ^{13}C n.m.r.



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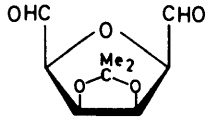
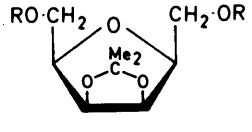
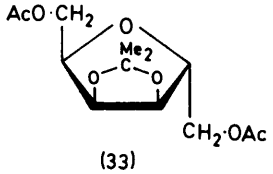


(30)



(31) R = H
(32) R = Ac



(33)

spectra of the D-galactitol (32), and the fact that it was optically inactive in solution, showed that a plane of symmetry was present in the molecule and that the compound was a D-galactitol derivative. A similar sequence of reactions on the methylamino-alcohol (20), derived from the D-*erythro*-L-*manno*-octonate (19), also gave the D-galactitol (32). The mixture of methylamino-alcohols (28), derived from the D-*erythro*-L-*altro*- and D-*erythro*-L-*allo*-octonates, (22) and (23), respectively, gave, after a similar sequence of reactions, the D-talitol (33), which exhibited more complex n.m.r. spectra and had a small optical rotation. These experiments established that the D-*erythro*-L-*gluco*- and D-*erythro*-L-*manno*-octonates, (17) and (19), and their derivatives had the 3*S*-configuration, and that the D-*erythro*-L-*altro*- and D-*erythro*-L-*allo*-octonates and their derivatives had the 3*R*-configuration. Clearly, the octonates (17) and (19) and their derivatives were epimeric only at C-2, as were the octonates (22) and (23) and their derivatives.

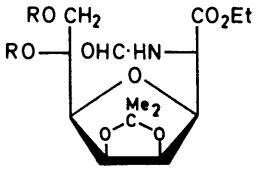
Studies [14] of the o.r.d. and c.d. spectra of α-amino-acids have revealed that all α-L-amino-acids give positive Cotton effects and α-D-amino- acids give negative effects, provided that no other interfering chromophoric system is present and that there is no unusual conformational restraint. The same relationship between configuration and the sign of the Cotton effect has been shown [15] to hold for α-methylamino-acids. The methylamino-ester (20) exhibited a negative Cotton effect at 235 nm and must therefore be a D-amino-acid derivative. The methylamino-ester (18) was unstable and reproducible

[14] G. C. Barrett in 'Amino-acids, Peptides and Proteins,' Chem. Soc. Specialist Periodical Report, 1976, vol. 7, p.19, and previous reports.
[15] J. Shoji, *J. Antibiotics*, 1973, **26**, 302.

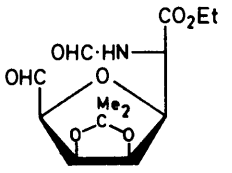
o.r.d. spectra could not be obtained, but as it can only differ from the methylamino-ester (20) at C-2, it must be an L-amino-acid derivative. These experiments established that the D-*erythro*-L-*gluco*-octonate (17) and its derivatives had the 2*S*-configuration, and that the D-*erythro*-L-*manno*-octonate (19) and its derivatives had the 2*R*-configuration.

reduction of the aldehyde and ester groups, and racemisation at C-2.) Similarly, D-*erythro*-L-*manno*-octonate (19) was converted into the D-*glycero*-L-*manno*-heptonate (39). Acetylation of the heptonates (37) and (39) gave the 7-acetates, (38) and (40), respectively.

The protecting groups of the octonates (17) and (19) and the heptonates (37) and (39) were removed by acidic



(34) R=H
(35) R=Ac



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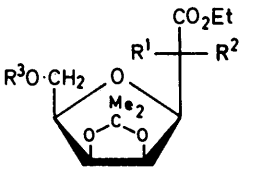
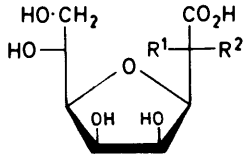
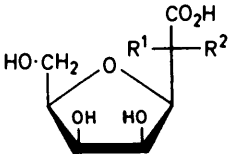


(37) R^1=NH·CHO, R^2=R^3=H
(38) R^1=NH·CHO, R^2=H, R^3=Ac
(39) R^1=R^3=H, R^2=NH·CHO
(40) R^1=H, R^2=NH·CHO, R^3=Ac

No indication of racemisation or 'anomerisation' during any of the experiments described above was found, and it is reasonable to assume that the derivatives of the octonates retained the original configuration at



(41) R^1=NH_2, R^2=H
(42) R^1=H, R^2=NH_2



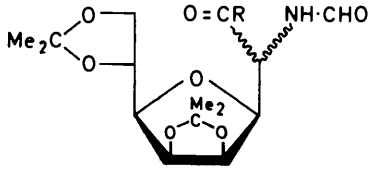
(43) R^1=NH_2, R^2=H
(44) R^1=H R^2=NH_2

C-2 and -3. Also, since it was established that the D-*erythro*-L-*gluco*-octonate (17) had the 2*S*,3*S*-configuration, and on the assumption that it was obtained by *cis*-hydrogenation of the oct-2-enonate (3), it followed

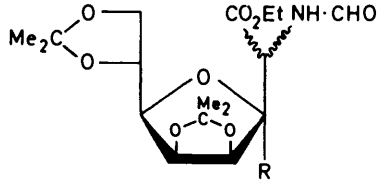
hydrolysis to afford the free amino-acids (41)—(44), in 40—60% yields. As expected,[14] the L-amino-acids (41) and (43) exhibited positive Cotton effects, whereas the D-amino-acids (42) and (44) exhibited negative effects. These configurational assignments were supported by the shifts in the specific rotations of the amino-acids (41)—(44) induced by acidification.[16]

To examine the possibility of applying these amino-acids and their derivatives to the preparation of peptides, the D-*erythro*-L-*gluco*-octonate (17) was de-esterified by brief treatment with barium hydroxide in methanol to give a C-2 epimeric mixture of the formylamino-acids (45), and these were converted into the dipeptides (46) and (47), in low yield, by the mixed anhydride method.[17]

Base-catalysed additions of alcohols and thiols across the double bond of the (*E*)-oct-2-enonate (3) occurred readily. The octulosonates (9) and (10), identical with



(45) R=OH
(46),(47) R=NH·CH_2·CO_2Et



(48),(49) R=O·CH_2Ph
(50) R=SMe

that the main product of the original formylaminomethylenation was (*E*)-ethyl 3,6-anhydro-2-deoxy-2-formylamino-4,5:7,8-di-*O*-isopropylidene-D-*manno*-oct-2-enonate (3).

The D-*erythro*-L-*gluco*-octonate (17) was converted into the D-*glycero*-L-*gluco*-heptonate (37) by selective removal of the 7,8-*O*-isopropylidene group to give the diol (34) [characterised as the diacetate (35)], cleavage of the diol with sodium periodate to give the aldehyde (36), and catalytic hydrogenation. (Treatment with sodium borohydride gave a mixture of products by simultaneous

the by-products obtained in the formylaminomethylenation of the lactone (1), were obtained, in high yield, by treatment of the (*E*)-oct-2-enonate (3) with ethanol containing a trace of sodium ethoxide (25 °C; 20 h). The reaction with benzyl alcohol containing a trace of sodium benzyl oxide was slower and was carried out at 50 °C over 4 days. No ester exchange took place under these conditions and the octulosonates (48) and (49)

[16] J. P. Greenstein and W. Winitz, 'Chemistry of the Amino Acids,' Wiley, New York, 1969, vol. 1, p. 83.
[17] See ref. 16, vol. 2, p. 970.

were isolated in high yield. The addition of methanethiol to the (*E*)-oct-2-enonate (3) in chloroform containing a trace of 1,5-diazabicyclo[4.3.0]non-5-ene (25 °C; 1 h) gave the two cysteine derivatives (50) as a mixture which was not separated.

Doublets between τ 4.50 and 4.82 which collapsed to singlets on addition of deuterium oxide (H-2) in the n.m.r. spectra of the octulosonates (9), (10), (48), and (49) and the cysteine derivatives (50) indicated that attack by the alcoholates took place at C-3 of the (*E*)-oct-2-enonate (3) and was followed by protonation at C-2. It was assumed that attack took place from the less hindered α-face of the (*E*)-oct-2-enonate (3).

A preliminary account of the effects of the nature of the lactone and the base on the reactions of ethyl isocyanoacetate with aldonic acid lactones has appeared.[18]

EXPERIMENTAL

T.l.c. and column chromatography were performed with silica gel (Merck). M.p.s were determined with a hot-stage apparatus. Optical rotations were measured with a Perkin-Elmer 241 polarimeter (*c* 1.0 ± 0.3) and i.r. spectra with a Perkin-Elmer 257 spectrophotometer for solutions in chloroform, unless otherwise stated. Proton n.m.r. spectra were recorded with a Varian HA-100 instrument and ^{13}C n.m.r. spectra with a Varian CFT-20 instrument for solutions in deuteriochloroform and with tetramethylsilane as internal standard, unless otherwise stated. Mass spectra were determined with an A.E.I. MS9 spectrometer by direct insertion. U.v. spectra were measured with a Unicam SP 800 spectrophotometer and o.r.d. and c.d. spectra with a JASCO J-20 automatic recording spectropolarimeter. Ethanol refers to aqueous 96% ethanol unless otherwise stated.

Formylaminomethylenation of 2,3:5,6-*Di*-O-*isopropylidene*-D-mannono-1,4-*lactone* (1) *with Ethyl Isocyanoacetate* (2).—A solution of the lactone (1) (22.7 g, 88 mmol) and ethyl isocyanoacetate (2) (10.0 g, 88 mmol) in dry tetrahydrofuran (200 ml) was added dropwise, with exclusion of moisture, to a stirred suspension of potassium hydride (7.1 g, 88 mmol; 50% suspension in oil) in dry tetrahydrofuran (200 ml) at −70 °C. The mixture was then allowed to warm up until evolution of hydrogen was observed (*ca.* −10 °C), and the rate of evolution was then controlled with a cooling bath. When evolution had ceased, the cooling bath was removed and the mixture was left at 25 °C for 4 h. The solvent was removed *in vacuo* (40 °C), aqueous acetic acid (7 ml in 400 ml of ice–water) was added, and the mixture was extracted with chloroform (3 × 200 ml). The combined extracts were washed with saturated aqueous sodium hydrogen carbonate until acid-free, dried ($MgSO_4$), filtered, and evaporated *in vacuo* to give a syrup (*ca.* 30 g).

The syrup was chromatographed and mixed fractions so obtained were rechromatographed with ethyl acetate–chloroform (1 : 1) as eluant to give a mixture of ethyl (ethyl 2-deoxy-2-formylamino-4,5:7,8-di-*O*-isopropylidene-α-D-*manno*-D-*glycero*-oct-3-ulo-3,6-furanosid)onate and its L-*glycero*-isomer, (9) and (10), as an oil (320 mg, 1%) identical with authentic material (see later). This was followed by a mixture of the *E*- and *Z*-isomers of ethyl 5-(2,5-anhydro-1-deoxy-1-formylamino-3,4:6,7-di-*O*-isopropylidene-D-*manno*-hept-1-enitol-1-yl)oxazole-4-carboxylate (8) as a pale yellow oil (3.2 g, 8%), $\nu_{max.}$ 3 360 (NH), 1 710 and 1 695 (CO), and 1 600 cm^{-1} (C=N), M^+ 438, τ 1.65 and 1.82 (1 H, 2d, $J_{CHO,NH}$ 11 and <1 Hz, simplifies on addition of D_2O, CHO), 1.97br (1 H, s, disappears on addition of D_2O, NH), 2.19 and 2.24 (1 H, 2s, H-2 of oxazole), 4.07 and 4.60 (1 H, 2d, $J_{3,4}$ 7 Hz, H-3), 5.22—6.24 (7 H, m, H-4, -5, -6, -7a,7b, O·CH_2·CH_3), and 8.37—8.76 (15 H, m, 4 CH_3 and O·CH_2·CH_3) (Found: M^+, 438.530. $C_{20}H_{26}N_2O_9$ requires M^+, 438.531).

Further elution gave (Z)-*ethyl* 3,6-*anhydro*-2-*deoxy*-2-*formylamino*-4,5:7,8-*di*-O-*isopropylidene*-D-manno-*oct*-2-*enonate* (4) as a syrup (1.6 g, 5%), $[\alpha]_D^{22}$ +112°, $\nu_{max.}$ 3 420 (NH) and 1 690 cm^{-1} (CO), M^+ 371, τ 1.63 and 1.81 (1 H, 2d, $J_{CHO,NH}$ 12 and <1 Hz, simplifies on addition of D_2O, CHO), 3.07br (1 H, d, $J_{NH,CHO}$ 12 Hz, disappears on addition of D_2O, NH), 4.20 (1 H, d, $J_{4,5}$ 5.5 Hz, H-4), 5.10 (1 H, m, H-5), 5.48—5.94 (6 H, m, H-6, -7, -8a, -8b, O·CH_2·CH_3), 8.54, 8.57, and 8.60 (12 H, 3s, 4 CH_3), and 8.69 (3 H, t, O·CH_2·CH_3) (Found: M^+, 371.158. $C_{17}H_{25}NO_8$ requires M^+, 371.158).

Then followed an oil which slowly crystallized. Recrystallization from ethyl acetate–hexane gave the E-*isomer* (3) (19.0 g, 58%), m.p. 105—107°, $[\alpha]_D^{22}$ +304°, $\nu_{max.}$ 3 410 (NH) and 1 680 cm^{-1} (CO), M^+ 371, τ 1.82 and 1.99 (1 H, 2d, $J_{CHO,NH}$ <1 and 12 Hz, simplifies with addition of D_2O, CHO), 3.03br and 3.24 (1 H, s and d, $J_{NH,CHO}$ 12 Hz, disappears on addition of D_2O, NH), 4.61 and 4.65 (1 H, 2d, $J_{4,5}$ 5.5 Hz, H-4), 5.15 and 5.21 (1 H, 2dd, $J_{5,4}$ 5.5, $J_{5,6}$ 3.5 Hz, H-5), 5.42—5.90 (6 H, m, H-6, -7, -8a, -8b, O·CH_2·CH_3), and 8.51—8.77 (15 H, m, 4 CH_3 and O·CH_2·CH_3) (Found: C, 55.0; H, 6.8; N, 3.8. $C_{17}H_{25}NO_8$ requires C, 55.0; H, 6.8; N, 3.7%).

Photolysis of Compound (3).—A solution of compound (3) (100 mg) in nitrogen-purged benzene–acetone (4 : 1; 1 ml) was irradiated (1 h) with unfiltered radiation from a medium-pressure mercury lamp. The solvent was removed *in vacuo* and the product was examined by n.m.r. spectroscopy. Signals at τ 4.20 [H-4 of compound (4)] and τ 4.61 and 4.65 [H-4 of compound (3)] showed that the mixture contained *ca.* 15% of compound (4). Irradiation for longer periods did not increase the yield of compound (4).

(E)-*Ethyl* 3,6-*Anhydro*-2-*deoxy*-2-*isocyano*-4,5:7,8-*di*-O-*isopropylidene*-D-manno-*oct*-2-*enoate* (11).—A solution of phosgene (320 mg, 3.2 mmol) in ethanol-free dichloromethane (6 ml) was added dropwise to a solution of compound (3) (1.113 g, 3 mmol) and triethylamine (1 ml) in refluxing ethanol-free dichloromethane (10 ml). Heating was continued for 20 min; the solution was then cooled and the precipitated triethylamine hydrochloride filtered off. The solvent was removed *in vacuo*, the residue was taken up in ethyl acetate (30 ml), the mixture was filtered, and the solvent was removed *in vacuo* to give the 2-*isocyano*-*compound* (11) as a pale yellow oil (t.l.c. showed that the compound was slightly contaminated) (335 mg, 95%), $\nu_{max.}$ 2 120 (NC:), 1 720 (CO), and 1 640 cm^{-1} (C=C), *m/e* 338 ($M^+ - CH_3$), τ 4.51 (1 H, d, $J_{4,5}$ 5.5 Hz, H-4), 5.14 (1 H, dd, $J_{5,4}$ 5.5, $J_{5,6}$ 3 Hz, H-5), 5.18—5.95 (6 H, m, H-6, -7, -8a, -8b, O·CH_2·CH_3), 8.56, 8.58, and 8.63 (12 H, 3s, 4 CH_3), and 8.70 (3 H, t, O·CH_2·CH_3) (Found: *m/e*, 338.342. $C_{16}H_{20}NO_7$ requires $M - CH_3$, 338.340).

Ethyl 5-(2,5-*Anhydro*-2-*deoxy*-1-*isocyano*-3,4:6,7-*di*-O-*isopropylidene*-D-manno-*hept*-1-*enitol*-1-*yl*)*oxazole*-4-*carboxylate* (12).—The oxazole (8) was treated as described for the

[18] S. J. Eitelman, R. H. Hall, and A. Jordaan, *J.C.S. Chem. Comm.*, 1976, 923.

preparation of compound (11); similar workup gave the oxazole (12) (t.l.c. showed that the compound was contaminated), $\nu_{max.}$ 2 120 (NC:), 1 720 (CO), and 1 640 cm^{-1} (C=C), M^+ 420, τ 2.14 (1 H, s, H-2 of oxazole), 4.58 (1 H, d, $J_{3,4}$ 8 Hz, H-3), *ca.* 5.17—*ca.* 6.06 (7 H, m, H-4, -5, -6, -7a, -7b, O·CH_2·CH_3), and 8.48—8.80 (15 H, m, 4 CH_3, O·CH_2·CH_3) (Found: M^+, 420.153. $C_{20}H_{14}N_2O_8$ requires M, 420.153).

(E)-*Ethyl* 2-*Acetamido*-4,5,7,8-*tetra*-O-*acetyl*-3,6-*anhydro*-2-*deoxy*-D-manno-*oct*-2-*enonate* (13).—Compound (3) (371 mg, 1 mmol) in aqueous dioxan containing 0.5N-hydrochloric acid (1 : 1; 10 ml) was heated at 100 °C for 4 h, then the solvents were removed *in vacuo* at 25 °C. Water (10 ml) was added to the residue and removed *in vacuo*, and ethanol (10 ml) was then added and evaporated off *in vacuo* to remove traces of acid. The residue (*ca.* 340 mg) was acetylated with acetic anhydride–pyridine in the usual manner to give an oil which was purified by chromatography with ethyl acetate as eluant to yield an oil which solidified. Recrystallization from ethyl acetate–hexane gave *compound* (13) (172 mg, 25%), m.p. 166—167°, $[\alpha]_D^{23}$ +124°, $\nu_{max.}$ 3 420 (NH) and 1 750 and 1 680 cm^{-1} (CO), M^+ 473, τ 3.00br (1 H, s, disappears on addition of D_2O, NH), 3.82 (1 H, d, $J_{4,5}$ 5 Hz, H-4), 4.32 (1 H, dd, $J_{5,4}$ 5, $J_{5,6}$ 3.5 Hz, H-5), 4.57 (1 H, octet, $J_{7,6}$ 9.5, $J_{7,8}$ 4.5 and 2 Hz, H-7), 5.28 (1 H, dd, $J_{6,7}$ 9.5, $J_{6,5}$ 3.5 Hz, H-6), 5.36 (1 H, dd, $J_{8a,8b}$ 12, $J_{8a,7}$ 2 Hz, H-8a), 5.76 (2 H, q, O·CH_2·CH_3), 5.78 (1 H, dd, $J_{8a,8b}$ 12, $J_{8b,7}$ 4.5 Hz, H-8b), 7.89, 7.92, 7.95, and 7.99 (15 H, 4s, 5 OAc), and 8.69 (3 H, t, O·CH_2·CH_3) (Found: C, 50.8; H, 6.0; N, 3.0. $C_{20}H_{27}NO_{12}$ requires C, 50.7; H, 5.8; N, 3.0%).

(E)-*Ethyl* 7,8-*Di*-O-*acetyl*-3,6-*anhydro*-2-*deoxy*-2-*formylamino*-4,5-O-*isopropylidene*-D-manno-*oct*-2-*enonate* (15).—Compound (3) (370 mg, 1 mmol) was hydrolysed as described for the preparation of compound (32) to give the diol (14) as an oil, M^+ 331. This was acetylated with acetic anhydride–pyridine; work-up gave an oil which solidified. Recrystallization from ethyl acetate–hexane gave compound (15) (353 mg, 85%), m.p. 125—126°, $[\alpha]_D^{20}$ +256°, $\nu_{max.}$ 3 400 (NH) and 1 740 and 1 700 cm^{-1} (CO), M^+ 415, τ 1.80 and 1.95 (1 H, s and d, $J_{CHO,NH}$ <1 and 11 Hz, simplifies on addition of D_2O, CHO), 3.04br and 3.25br (1 H, s and d, $J_{NH,CHO}$ 11 Hz, disappears on addition of D_2O, NH), 4.53—4.72 (2 H, m, H-4, -7), 5.13—5.44 (3 H, m, H-5, -6, -8a), 5.68—5.90 (3 H, m, H-8b, O·CH_2·CH_3), 7.92 (6 H, s, 2 OAc), 8.57—8.80 (9 H, m, 2 CH_3, O·CH_2·CH_3) (Found: C, 52.0; H, 6.1; N, 3.2. $C_{18}H_{25}NO_{10}$ requires C, 52.1; H, 6.1; N, 3.4%).

Attempts to prepare (E)-*Ethyl* 3,6-*Anhydro*-2-*deoxy*-2-*formylamino*-4,5-O-*isopropylidene*-D-lyxo-*hept*-2-*enonate*.—The diol (14) was treated with sodium periodate as described for the preparation of compound (32). Work-up gave compound (16) as a pale yellow oil, M^+ 299. Attempts were made to reduce the aldehyde function selectively by hydrogenation over platinum, palladium, and nickel catalysts at various pressures. In all cases mixtures of products were obtained. Similarly, mixtures were obtained with equivalent amounts of sodium borohydride, sodium triacetoxyborohydride, and lithium tri-t-butoxyaluminium hydride.

Ethyl 3,6-*Anhydro*-2-*deoxy*-2-*formylamino*-4,5:7,8-*di*-O-*isopropylidene*-D-erythro-L-gluco-*octonate* (17) *and its* L-manno-*Isomer* (19).—Compound (3) (5 g, 13.5 mmol) and W2 Raney nickel (*ca.* 1 ml) in ethanol (99%; 100 ml) were shaken with hydrogen (50 lb in^{-2}) at 25 °C until all compound (3) had reacted (2—4 days), as shown by t.l.c. The catalyst and solvent were removed to leave an oil (*ca.* 5 g). Chromatography with ethyl acetate–chloroform (7 : 3) as eluant gave the L-gluco-*isomer* (17) as an oil (4.5 g, 90%), $[\alpha]_D^{22}$ −6°, $\nu_{max.}$ 3 440 (NH) and 1 730 and 1 680 cm^{-1} (CO), *m/e* 358 (M^+ − CH_3), τ 1.83 and 1.98 (1 H, 2d, $J_{CHO,NH}$ <1 and 12 Hz, simplifies on addition of D_2O, CHO), 3.60br (1 H, d, $J_{NH,2}$ 8 Hz, disappears on addition of D_2O, NH), 5.15 (1 H, dd, $J_{2,NH}$ 8, $J_{2,3}$ 5.5 Hz, simplifies with addition of D_2O, H-2), *ca.* 5.18—5.30 (2 H, m, H-4, -5), 5.48—6.08 (6 H, m, H-3, -7, -8a, -8b, O·CH_2·CH_3), 6.43 (1 H, dd, $J_{6,7}$ 7, $J_{6,5}$ 3 Hz, H-6), 8.54, 8.56, 8.62, and 8.69 (12 H, 4s, 4 CH_3), and 8.72 (3 H, t, O·CH_2·CH_3) (Found: *m/e* 358.152. $C_{16}H_{24}NO_8$ requires M − CH_3, 358.150).

Further elution gave an oil which slowly crystallized. Recrystallization from ethyl acetate–hexane gave the L-manno-*isomer* (19) (300 mg, 6%), m.p. 137—138°, $[\alpha]_D^{22}$ +7°, $\nu_{max.}$ 3 420 (NH) and 1 740 and 1 680 cm^{-1} (CO), *m/e* 358 (M^+ − CH_3), τ 1.76 (1 H, s, CHO), 3.17br (1 H, d, $J_{NH,2}$ 9 Hz, disappears on addition of D_2O, NH), 4.73 (1 H, dd, $J_{2,NH}$ 9, $J_{2,3}$ 5.5 Hz, simplifies on addition of D_2O, H-2), *ca.* 5.22 (2 H, m, H-4, -5), 5.52—6.21 (6 H, m, H-3, -7, -8a, -8b, O·CH_2·CH_3), 6.42 (1 H, m, H-6), 8.45, 8.56, 8.62, and 8.66 (12 H, 4s, 4 CH_3), and 8.70 (3 H, t, O·CH_2·CH_3) (Found: C, 54.6; H, 7.4; N, 3.8. $C_{17}H_{27}NO_8$ requires C, 54.7; H, 7.3; N, 3.8%).

Ethyl 3,6-*Anhydro*-2-*deoxy*-2-*formylamino*-4,5:7,8-*di*-O-*isopropylidene*-D-erythro-L-altro-*octonate* (22) *and its* L-allo-*Isomer* (23).—The L-gluco-isomer (17) (860 mg, 2.3 mmol) was dissolved in ethanol (99%; 20 ml) containing a trace of sodium ethoxide (*ca.* 3 mg) and the solution was left at 25 °C for 7 days. The solvent was removed *in vacuo*, chloroform (20 ml) was added to the residue, and the solution was washed with saturated aqueous sodium hydrogen carbonate (2 × 20 ml). The chloroform solution was dried ($MgSO_4$) and the solvent was removed *in vacuo* to give an oil which was chromatographed with ethyl acetate as eluant to yield a mixture of the L-*altro*- and L-*allo*-isomers (22) and (23) as a clear syrup (*ca.* 1 : 1 by n.m.r. spectroscopy; 410 mg, 48%), $\nu_{max.}$ 3 410 (NH) and 1 740 and 1 690 cm^{-1} (CO), *m/e* 358 (M^+ − CH_3), τ 1.75br (1 H, s, sharpens on addition of D_2O, CHO), 1.79br (1 H, s, sharpens on addition of D_2O, CHO), 3.46br (2 H, d, $J_{NH,2}$ *ca.* 8 Hz, disappears on addition of D_2O, 2 NH), 5.04—5.34 (6 H, m, simplifies on addition of D_2O, H-2, -4, -5), 5.61—6.17 (14 H, m, H-3, -6, -7, -8a, -8b, O·CH_2·CH_3), and 8.51—8.79 (30 H, m, 4 OAc, O·CH_2·CH_3) (Found: *m/e*, 358.152. $C_{16}H_{24}NO_8$ requires M − CH_3, 358.150).

Further elution gave an oil (186 mg, 22%), identical with the L-*gluco*-starting material (17). This was followed by the L-manno-*isomer* (19), a crystalline solid (138 mg, 16%), identical with that described earlier.

No isomerisation was observed on leaving compound (17) in pyridine for 2 days.

Ethyl 3,6-*Anhydro*-2-*deoxy*-2-*methylamino*-4,5:7,8-*di*-O-*isopropylidene*-D-erythro-L-gluco-*octonate* (18).—Diborane (5 mmol) generated externally by the iodine–sodium borohydride method [14] was carried over into a solution of compound (17) (373 mg, 1 mmol) in dry tetrahydrofuran with a stream of dry nitrogen. The solution was protected from moisture and left at 25 °C for 6 h. Ethanol (*ca.* 1 ml) was added to the solution, which was stirred for 5 min, and solvents were removed *in vacuo*. Ethanol (10 ml) was added to the residue, the resulting solution was refluxed (30 min), and the solvent was removed *in vacuo*. Aqueous

sodium hydrogen carbonate (20 ml) was added to the residue and the mixture was stirred (1 h). The mixture was extracted with ethyl acetate (2 × 20 ml); the combined extracts were dried (Na_2SO_4) and the solvent was removed *in vacuo* to give an oil (*ca.* 300 mg). Chromatography with ethyl acetate as eluant gave *compound* (18) as a pale yellow oil (t.l.c. showed that the compound was decomposing) (105 mg, 29%), $\nu_{max.}$ 3 400 (NH) and 1 720 cm^{-1} (CO), M^+ 359, τ *ca.* 5.26 (2 H, m, H-4, -5), 5.60 (1 H, m, $J_{7,8}$ 8 and 5, $J_{7,6}$ 5 Hz, H-7), 5.78 (2 H, q, O·CH_2·CH_3), *ca.* 5.95 (2 H, m, H-8a, -8b), 6.17—6.56 (3 H, m, H-2, -3, -6), 7.56 (3 H, s, NCH_3), 8.55, 8.57, 8.64, and 8.71 (12 H, 4s, 4 CH_3), and 8.71 (3 H, t, O·CH_2·CH_3) (Found: *m/e* 344.174. $C_{16}H_{26}NO_7$ requires $M - CH_3$, 344.171).

Ethyl 3,6-*Anhydro*-2-*deoxy*-2-*methylamino*-4,5:7,8-*di*-O-*isopropylidene*-D-erythro-L-manno-*octonate* (20).—Compound (19) was treated with diborane as described for the preparation of compound (18) to give, after chromatography with ethyl acetate as eluant, *compound* (20) as an oil (53%), $[\alpha]_D^{20}$ −30°, $\nu_{max.}$ 3 510 and 3 320 (NH) and 1 720 cm^{-1} (CO), M^+ 359, τ *ca.* 5.25 (2 H, m, H-4, -5), 5.62 (1 H, m, $J_{7,8}$ 7 and 5.5, $J_{7,6}$ 5.5 Hz, H-7), 5.78 (2 H, q, O·CH_2·CH_3), 5.97—6.04 (2 H, m, H-8a, -8b), *ca.* 4.50 (3 H, m, H-2, -3, -6), 7.61 (3 H, s, NCH_3), 8.50, 8.60, and 8.65 (12 H, 3s, 4 CH_3), and 8.72 (3 H, t, O·CH_2·CH_3) (Found: *m/e*, 344.172. $C_{16}H_{26}NO_7$ requires $M - CH_3$, 344.171).

3,6-*Anhydro*-2-*deoxy*-2-*formylamino*-4,5:7,8-*di*-O-*isopropylidene*-D-erythro-L-gluco-*octitol* (25).—*Method* (*a*). A solution of sodium borohydride (500 mg, 13.2 mmol) in ethanol (96%, 100 ml) was added dropwise to a solution of compound (17) (1.0 g, 2.7 mmol) in ethanol (50 ml) at 0 °C. The mixture was stirred at 25 °C (3 h), acetic acid (1 ml) was added, the mixture was filtered, and the solvent was removed *in vacuo*. Absolute ethanol (50 ml) was added to the residue, the mixture was filtered through Celite, and the solvent was removed *in vacuo*. The residue was taken up in chloroform (50 ml), and the solution was dried ($MgSO_4$) and filtered through Celite. Removal of solvent left an oil which was chromatographed with ethyl acetate–ethanol (9 : 1) as eluant to give an oil which slowly crystallized. Recrystallization from ethyl acetate–hexane gave the *octitol* (25) (315 mg, 31%), m.p. 149—150°, $[\alpha]_D^{22}$ −33°, $\nu_{max.}$ 3 430 (NH) and 1 690 cm^{-1} (CO), *m/e* 316 ($M^+ - CH_3$), τ 1.84 and 1.96 (1 H, 2d, $J_{CHO,NH}$ *ca.* 1 and 12 Hz, simplifies on addition of D_2O, CHO), 3.49br (1 H, d, $J_{NH,2}$ 6 Hz, disappears on addition of D_2O, NH), 5.21 (2 H, m, H-4, -5), 5.50—6.50 (8 H, m, simplifies on addition of D_2O, H-1a, -1b, -2, -3, -6, -7, -8a, -8b), and 8.52, 8.56, 8.62, and 8.66 (12 H, 4s, 4 CH_3) (Found: C, 54.6; H, 7.9; N, 4.3. $C_{15}H_{25}NO_7$ requires C, 54.4; H, 7.6; N, 4.2%).

Method (*b*). Lithium aluminium hydride (152 mg, 4 mmol) was added in small portions to a solution of compound (17) (1.0 g, 2.7 mmol) in dry tetrahydrofuran (50 ml) at 0 °C. The mixture was stirred (3 h; 25 °C), aqueous tetrahydrofuran (50%; 5 ml) was added to destroy the excess of hydride, and the mixture was stirred for a further 1 h, filtered, and evaporated *in vacuo*. The residue was taken up in chloroform (50 ml); the solution was dried ($MgSO_4$) and evaporated *in vacuo* to give an oil. Chromatography and recrystallization, as in method (a), gave the octitol (25) (350 mg, 39%).

3,6-*Anhydro*-2-*deoxy*-4,5:7,8-*di*-O-*isopropylidene*-2-*methylamino*-D-erythro-L-gluco-*octitol* (26).—A solution of compound (17) (1.0 g, 2.7 mmol) in dry tetrahydrofuran (30 ml) was added dropwise to a suspension of lithium aluminium hydride (500 mg, 13 mmol) in dry tetrahydrofuran (20 ml) at 0 °C. The mixture was stirred for 3 h at 25 °C, then treated as described for the preparation of compound (25) [method (b)]; work-up gave an oil which was chromatographed with ethanol as eluant to afford an oil which crystallized. Recrystallization from ethyl acetate–hexane gave the *methylamino-compound* (26) (560 mg, 65%), m.p. 43—48°, $[\alpha]_D^{22}$ −1°, $\nu_{max.}$ 3 320 cm^{-1} (NH, OH), *m/e* 302 ($M^+ - CH_3$), τ 5.25 (2 H, m, H-4, -5), 5.60 (1 H, m, H-7), 5.82—6.10 (2 H, m, H-8a, -8b), 6.14—6.58 (4 H, m, simplifies on addition of D_2O, H-1a, -1b, -3, -6), 7.05 (1 H, m, simplifies on addition of D_2O, H-2), 7.48br (2 H, s, disappears on addition of D_2O, OH, NH), 7.55 (3 H, s, NCH_3), and 8.53, 8.55, 8.62, and 8.67 (12 H, 4s, 4 CH_3) (Found: C, 56.6; H, 8.8; N, 4.5. $C_{15}H_{27}NO_6$ requires C, 56.8; H, 8.6; N, 4.4%).

3,6-*Anhydro*-2-*deoxy*-4,5:7,8-*di*-O-*isopropylidene*-2-*methylamino*-D-erythro-L-manno-*octitol* (27).—Compound (19) (746 mg, 2 mmol) was treated with an excess of lithium aluminium hydride and the product worked up as described for its isomer (17). Chromatography with ethanol as eluant gave a solid which was recrystallized from benzene–hexane, and then sublimed (106 °C and 0.1 mmHg) to give the *octitol* (27) (370 mg, 58%), m.p. 119—120°, $[\alpha]_D^{20}$ −9°, $\nu_{max.}$ *ca.* 3 500—3 300 cm^{-1} (NH, OH), *m/e* 302 ($M^+ - CH_3$), τ 5.26 (2 H, m, H-4, -5), 5.54—5.72 (1 H, m, H-7), 5.84—6.00 (2 H, m, H-8a, -8b), 6.15—6.54 (4 H, m, simplifies on addition of D_2O, H-1a, -1b, -3, -6), 7.10 (1 H, m, simplifies on addition of D_2O, $J_{2,1a} = J_{2,1b} = J_{2,3} = 4$ Hz, H-2), 7.57 (3 H, s, NCH_3), 7.92br (2 H, s, disappears on addition of D_2O, OH, NH), and 8.55, 8.59, 8.64, and 8.68 (12 H, 4s, 4 CH_2) (Found: C, 56.9; H, 8.8; N, 4.6. $C_{15}H_{27}NO_6$ requires C, 56.8; H, 8.6; N, 4.4%).

1,6-*Di*-O-*acetyl*-2,5-*anhydro*-3,4-O-*isopropylidene*-D-*galactitol* (32).—Compound (26) (396 mg, 1.25 mmol) was stirred in aqueous acetic acid (70%; 5 ml) at 50—60 °C for 70 min, and the solvents were then removed *in vacuo* at 25 °C. Water (5 ml) was added to the residue and removed *in vacuo*, and then ethanol (5 ml) was added and evaporated off *in vacuo* to remove all traces of acetic acid and water. Compound (29), obtained as an oil, *m/e* 262 ($M^+ - CH_3$), was taken up in aqueous ethanol (50%; 10 ml), sodium periodate (850 mg, 4 mmol) was added in portions over 30 min at 0 °C, the mixture was stirred at 25 °C (4 h), ethylene glycol (10 drops) was added, the mixture was filtered, and the filtrate was evaporated. Ethanol (5 ml) was added to the residue; the mixture was filtered and the solvent was removed *in vacuo*. Ethanol (5 ml) was again added to the residue, the mixture was filtered, and the solvent was removed. The residue was then taken up in chloroform (25 ml) and the solution was dried ($MgSO_4$) and filtered through Celite to give the dialdehyde (30) as an oil, *m/e* 185 ($M^+ - CH_3$). This oil was treated with sodium borohydride (380 mg, 10 mmol) in aqueous ethanol (90%) and the product worked up as described for the preparation of compound (25) [method (a)] to give compound (31) as a syrup, *m/e* 189 ($M^+ - CH_3$). This syrup was acetylated with acetic anhydride–pyridine to give a crystalline solid which was taken up in chloroform–ethyl acetate (4 : 1) and passed through a short column of silica. Removal of the solvents left a solid which was recrystallized from ethyl acetate–hexane to give the D-*galactitol* (32) [120 mg, 42% from compound (26)], m.p. 114—115°, $[\alpha]_D^{22}$ 0°, $\nu_{max.}$ 1 730 cm^{-1} (CO), *m/e* 273 ($M^+ - CH_3$), τ 5.27 (2 H, m, H-3, -4), 5.51 (2 H, dd, $J_{1a,1b}$ and

$J_{6a,6b}$ 12, $J_{1a,2}$ and $J_{6a,5}$ 4.5 Hz, H-1a, -6a), 5.77 (2 H, dd, $J_{1b,1a}$ and $J_{6b,6a}$ 12, $J_{1b,2}$ and $J_{6b,5}$ 7 Hz, H-1b, -6b), 6.16—6.31 (2 H, m, H-2, -5), 7.91 (6 H, s, 2 OAc), and 8.56 and 8.68 (6 H, 2s, $2CH_3$), δ_C 172.0 (2 C, 2 CH_3·*C*O), 113.8 [1 C, *C*$(CH_3)_2$], 81.0 and 79.7 (4 C, C-2, -5 and C-3, -4), 62.6 (2 C, C-1, -6), 25.9 and 24.9 [2 C, C(*C*$H_3)_2$], and 20.7 (2 C, 2*C*H_3·CO) (Found: C, 54.3; H, 7.1. $C_{13}H_{20}O_7$ requires C, 54.2; H, 7.0%).

Similarly, compound (27) was converted into the D-galactitol (32) (47%).

1,6-*Di*-O-*acetyl*-2,5-*anhydro*-3,4-O-*isopropylidene*-D-*talitol* (33).—The mixture of L-*altro*- and L-*allo*-isomers [(22) and (23)] was treated with an excess of lithium aluminium hydride as described for the preparation of compound (26). Chromatography with ethyl acetate–ethanol (4 : 1) as eluant gave a mixture of methylamino-compounds (28) as an oil, *m/e* 302 ($M^+ - CH_3$). These compounds were not characterised but treated as described for the preparation of compound (32) to yield an oil which was chromatographed with ethyl acetate–hexane (1 : 1) as eluant to give the D-*talitol* (33) as an oil [29% from compounds (22) and (23)], $[\alpha]_D^{20}$ +3°, $\nu_{max.}$ 1 730 cm^{-1} (CO), *m/e* 273 ($M^+ - CH_3$), τ 5.18—5.37 (2 H, m, H-3, -4), 5.48—6.01 (6 H, m, H-1a, -1b, -2, -5, -6a, -6b), 7.93 (6 H, s, 2 OAc), and 8.53 and 8.69 (6 H, 2s, 2 CH_3), δ_C 170.4 and 170.1 (2 C, 2 CH_3·*C*O), 113.4 [1 C, *C*$(CH_3)_2$], 83.0, 82.2, 81.3, and 79.5 (4 C, C-2, -3, -4, -5), 63.8 and 63.3 (2 C, C-1, -6), 26.3 and 25.1 [2 C, C(*C*$H_3)_2$], and 20.8 (2 C, 2 *C*H_3CO) (Found: *m/e*, 273.097. $C_{13}H_{20}O_7$ requires $M - CH_3$, 273.097).

Ethyl 7,8-*Di*-O-*acetyl*-3,6-*anhydro*-2-*deoxy*-2-*formylamino*-4,5-O-*isopropylidene*-D-erythro-L-gluco-*octonate* (35).—Compound (17) (150 mg, 0.4 mmol) was partially hydrolysed and the product worked up as described for the preparation of compound (32) to give the *diol* (34), *m/e* 318 ($M^+ - CH_3$). The diol (34) was acetylated with acetic anhydride–pyridine to give an oil (*ca.* 150 mg), which was chromatographed with ethyl acetate as eluant to yield an oil which crystallized. Recrystallization from diethyl ether–hexane gave the *diacetate* (35) (126 mg, 75%), m.p. 71—73°, $[\alpha]_D^{22}$ −7°, $\nu_{max.}$ 3 440 (NH) and 1 740 and 1 690 cm^{-1} (CO), *m/e* 402 ($M^+ - CH_3$), τ 1.81 and 1.96 (1 H, 2d, $J_{CHO,NH}$ <1 and 12 Hz, simplifies on addition of D_2O, CHO), 3.49br (1 H, d, $J_{NH,2}$ 6 Hz, disappears on addition of D_2O, NH), 4.72 (1 H, m, H-7), 5.13—5.29 (3 H, m, simplifies on addition of D_2O, H-2, -4, -5), 5.46 (1 H, dd, $J_{8a,8b}$ 12, $J_{8a,7}$ 3 Hz, H-8a), 5.79 (2 H, q, O·CH_2·CH_3), 5.82 (1 H, dd, $J_{8b,8a}$ 12, $J_{8b,7}$ 6 Hz, H-8b), 6.00 (1 H, dd, $J_{3,2}$ 6, $J_{3,4}$ 3 Hz, H-3), 6.29 (1 H, dd, $J_{6,7}$ 7.5, $J_{6,5}$ 4 Hz, H-6), 7.94 (6 H, s, 2 OAc), 8.58 and 8.73 (6 H, 2s, 2 CH_3), and 8.73 (3 H, t, O·CH_2·CH_3) (Found: C, 51.5; H, 6.5; N, 3.4. $C_{18}H_{27}NO_{10}$ requires C, 51.8; H, 6.5; N, 3.5%).

Ethyl 3,6-*Anhydro*-2-*deoxy*-2-*formylamino*-4,5-O-*isopropylidene*-D-glycero-L-gluco-*heptonate* (37) *and its* 7-O-*Acetyl Analogue* (38).—The diol (34) (3.75 g, 12 mmol) in aqueous ethanol (50%; 100 ml) was treated with sodium periodate (5 g) as described for the preparation of compound (32). Work up gave compound (36) as an oil, M^+ 301. Compound (36) was hydrogenated over Raney nickel in aqueous ethanol (80%; 100 ml) at 50 lb in^{-2} and 25 °C for 16 h. Filtration through Celite and removal of the solvents gave a clear syrup which was chromatographed with ethyl acetate–ethanol (19 : 1) to afford an oil which solidified on trituration with ethyl acetate. Recrystallization from ethyl acetate–hexane gave the *heptonate* (37) [3.1 g, 85% from compound (17)], m.p. 130—131°, $[\alpha]_D^{22}$ −6°, $\nu_{max.}$ 3 600 (OH), 3 430 (NH), and 1 740 and 1 690 cm^{-1} (CO), *m/e* 288 ($M^+ - CH_3$), τ 1.84 and 1.98br (1 H, s and d, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 3.02br (1 H, d, $J_{NH,2}$ 8 Hz, disappears on addition of D_2O, NH), 5.12—5.32 (3 H, m, simplifies on addition of D_2O, H-2, -4, -5), 5.80 (2 H, q, O·CH_2·CH_3), 6.01 (1 H, dd, $J_{3,2}$ 6, $J_{3,4}$ 3.5 Hz, H-3), 6.14 (2 H, m, simplifies on addition of D_2O, H-7a, -7b), 6.27—6.41 (1 H, m, H-6), 6.95br (1 H, s, disappears on addition of D_2O, OH), 8.56 and 8.73 (6 H, 2s, 2 CH_3), 8.73 (3 H, t, O·CH_2·CH_3) (Found: C, 51.4; H, 7.0; N, 4.4. $C_{13}H_{21}NO_7$ requires C, 51.5; H, 7.0; N, 4.6%).

Compound (37) was acetylated with acetic anhydride–pyridine to give the 7-*O-acetyl compound* (38) as an oil (98%), $[\alpha]_D^{22}$ +4°, $\nu_{max.}$ 3 420 (NH) and 1 740 and 1 690 cm^{-1} (CO), *m/e* 330 ($M^+ - CH_3$), τ 1.79 and 1.92br (1 H, s and d, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 3.48br (1 H, d, $J_{NH,2}$ 7 Hz, disappears on addition of D_2O, NH), 5.09—5.31 (3 H, m, simplifies on addition of D_2O, H-2, -4, -5), *ca.* 5.50—5.87 (4 H, m, H-7a, -7b, O·CH_2·CH_3), 5.98 (1 H, dd, $J_{3,2}$ 5, $J_{3,4}$ 3 Hz, H-3), 6.14—6.30 (1 H, m, H-6), 7.90 (3 H, s, OAc), 8.55 and 8.68 (6 H, 2s, 2 CH_3), and 8.70 (3 H, t, O·CH_2·CH_3) (Found: *m/e*, 330.119. $C_{14}H_{20}NO_8$ requires $M - CH_3$, 330.119).

Ethyl 3,6-*Anhydro*-2-*deoxy*-2-*formylamino*-4,5-O-*isopropylidene*-D-glycero-L-manno-*heptonate* (39) *and its* 7-O-*Acetyl Analogue* (40).—Compound (19) was hydrolysed to a diol which was cleaved to give an aldehyde that was reduced as described for the preparation of compound (31) to yield an oil which solidified. Recrystallization from ethyl acetate–hexane gave the *heptonate* (39) [84% from compound (19)], m.p. 153—155°, $[\alpha]_D^{22}$ +13°, $\nu_{max.}$ 3 600 (OH), 3 430 (NH), and 1 740 and 1 690 cm^{-1} (CO), *m/e* 288 ($M^+ - CH_3$), τ 1.78br and 1.99 (1 H, s and d, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 3.12br (1 H, d, $J_{NH,2}$ 9 Hz, disappears on addition of D_2O, NH), 4.74 (1 H, dd, $J_{2,NH}$ 9, $J_{2,3}$ 6 Hz, simplifies on addition of D_2O, H-2), 5.25 (2 H, m, H-4, -5), 5.76 (2 H, q, O·CH_2·CH_3), 6.00 (1 H, dd, $J_{3,2}$ 6, $J_{3,4}$ 3 Hz, H-3), 6.08—6.38 (3 H, m, simplifies on addition of D_2O, H-6, -7a, -7b), 7.45br (1 H, s, disappears on addition of D_2O, OH), 8.48 and 8.73 (6 H, 2s, 2 CH_3), and 8.73 (3 H, t, O·CH_2·CH_3) (Found: C, 51.5; H, 6.9; N, 4.7. $C_{13}H_{21}NO_7$ requires C, 51.5; H, 7.0; N, 4.6%).

Compound (39) was acetylated with acetic anhydride–pyridine to give an oil which crystallized. Recrystallization gave the 7-O-*acetyl-compound* (40) (93%), m.p. 108—109°, $[\alpha]_D^{22}$ +30°, $\nu_{max.}$ 3 440 (NH) and 1 735 and 1 690 cm^{-1} (CO), *m/e* 330 ($M^+ - CH_3$), τ 1.78br and 1.98 (1 H, s and d, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 3.17br (1 H, d, $J_{NH,2}$ 9 Hz, disappears on addition of D_2O, NH), 4.72 (1 H, dd, $J_{2,NH}$ 9, $J_{2,3}$ 6 Hz, simplifies on addition of D_2O, H-2), 5.24 (2 H, m, H-4, -5), 5.44—5.90 (4 H, m, H-7a, -7b, O·CH_2·CH_3), 6.02 (1 H, dd, $J_{3,2}$ 6, $J_{3,4}$ 2 Hz, H-3), 6.11—6.28 (1 H, m, H-6), 7.92 (3 H, s, OAc), 8.48 and 8.70 (6 H, 2s, 2 CH_3), and 8.71 (3 H, t, O·CH_2·CH_3) (Found: C, 52.5; H, 6.8; N, 4.1. $C_{15}H_{23}NO_8$ requires C, 52.2; H, 6.7; N, 4.1%).

2-*Amino*-3,6-*anhydro*-2-*deoxy*-D-erythro-L-gluco-*octonic Acid* [L-2-(β-D-*Mannofuranosyl*)*glycine*] (41).—Compound (17) (300 mg, 0.8 mmol) was stirred in aqueous 0.5N-hydrochloric acid (15 ml) at 96 °C for 5 h. The acid was removed *in vacuo* (<30 °C) and the residue was taken up in water (10 ml). The solution was passed through a short column of basic resin (Amberlite IR-45 OH; 15 ml), the column was flushed with water, and the solvent was removed *in vacuo* (<30 °C) to give a solid. Recrystallization from

water–ethanol gave the L-*amino-acid* (41) as needles (111 mg, 58%), decomp. *ca.* 205°, $[\alpha]_D^{20}$ −60° (H_2O), $[\alpha]_D^{20}$ −52° (aq. 0.5N-HCl); o.r.d. (*c* 1.3 × 10^{-3} in aq. 0.5N-HCl), $[\phi]_{219}$ 0°, $[\phi]_{224}$ +290°, $[\phi]_{232}$ 0° (Found: C, 40.6; H, 6.5; N, 5.8. $C_8N_{15}HO_7$ requires C, 40.5; H, 6.4; N, 5.9%).

2-*Amino*-3,6-*anhydro*-2-*deoxy*-D-erythro-L-manno-*octonic Acid* [D-2-(β-D-*Mannofuranosyl*)*glycine*] (42).—Compound (19) (300 mg, 0.8 mmol) was hydrolysed as described for the preparation of compound (41). Work-up gave a solid. Attempts to recrystallize the material gave an amorphous powder which was dried to give the D-*amino-acid* (42) (78 mg, 41%), decomp. *ca.* 140°, $[\alpha]_D^{20}$ +12° (H_2O), $[\alpha]_D^{20}$ −6° (aq. 0.5N-HCl); o.r.d. (*c* 1.4 × 10^{-3} in aq. 0.5N-HCl), $[\phi]_{210}$ 0°,$[\phi]_{220}$ −800°, $[\phi]_{234}$ 0° (Found: C, 40.4; H, 6.2; N, 5.7%).

2-*Amino*-3,6-*anhydro*-2-*deoxy*-D-glycero-L-gluco-*heptonic Acid* [L-2-(β-D-*Lyxofuranosyl*)*glycine*] (43).—Compound (37) (1.65 g, 5.5 mmol) was hydrolysed as described for compound (41). Work-up gave a solid which was recrystallized from water–ethanol to give the L-*amino-acid* (43) as plates (670 mg, 59%), decomp. *ca.* 217°, $[\alpha]_D^{20}$ −48° (H_2O), $[\alpha]_D^{20}$ −29° (aq. 0.5N-HCl); o.r.d. (*c* 1.7 × 10^{-3} in aq. 0.5N-HCl), $[\phi]_{210}$ 0°, $[\phi]_{223}$ +2 040°, $[\phi]_{260}$ +1 000° (Found: C, 40.4; H, 6.4; N, 6.6. $C_7H_{13}NO_6$ requires C, 40.6; H, 6.3; N, 6.8%).

2-*Amino*-3,6-*anhydro*-2-*deoxy*-D-glycero-L-manno-*heptonic Acid* [D-2-(β-D-*Lyxofuranosyl*)*glycine*] (44).—Compound (39) (200 mg, 0.66 mmol) was hydrolysed as described for the preparation of compound (41) and work-up gave a solid. Attempts to recrystallize the material gave an amorphous solid which was dried to give the D-*amino-acid* (44) (73 mg, 54%), decomp. *ca.* 100°, $[\alpha]_D^{20}$ +41° (H_2O), $[\alpha]_D^{20}$ +18° (aq. 0.5N-HCl); o.r.d. (*c* 1.3 × 10^{-3} in aq. 0.5N-HCl), $[\phi]_{208}$ 0°, $[\phi]_{219}$ −890°, $[\phi]_{241}$ 0° (Found: C, 40.2; H, 6.0; N, 6.9%).

3,6-*Anhydro*-2-*deoxy*-1-N-*ethoxycarbonylmethyl*-2-*formylamino*-4,5:7,8-*di*-O-*isopropylidene*-D-erythro-L-gluco-*octonamide and its* L-manno-*Isomer*, (46) *and* (47).—Compound (17) (1.23 g, 3.3 mmol) was added to a suspension of barium hydroxide (hydrated) (2.0 g, 6.3 mmol) in refluxing methanol (50 ml). After 30 min the mixture was neutralised with carbon dioxide and filtered hot, and the solvent was removed *in vacuo*. The residue obtained was stirred with refluxing ethyl acetate (50 ml), the solution was filtered, and the solvent was removed *in vacuo* to afford a residue that was stirred with chloroform (25 ml) (20 °C). The mixture was filtered and the solvent was removed *in vacuo* to give the acids (45) as a glass (*ca.* 1.2 g).

Ethyl chloroformate (0.32 ml, 3.3 mmol) was added dropwise to a solution of the acids (45) (1.2 g) and triethylamine (0.46 ml, 3.3 mmol) in dry ethanol-free chloroform (20 ml) at −10 °C and stirring was continued for 30 min. A solution of ethyl glycinate hydrochloride (460 mg, 3.3 mmol) and triethylamine (0.46 ml, 3.3 mmol) in dry ethanol-free chloroform (20 ml) was added dropwise at −10 °C. After 1 h at −10 °C the temperature of the solution was raised to 25 °C. After 75 h the solution was washed (1 × 20 ml water, 1 × 20 ml N-sulphuric acid, 1 × 20 ml saturated aqueous sodium hydrogen carbonate, and 1 × 20 ml water), dried ($MgSO_4$), and evaporated *in vacuo* to give an oil (*ca.* 600 mg). Chromatography with ethyl acetate as eluant gave two compounds (*ca.* 50 mg of each) which were not further investigated. [Mass spectrometry indicated that their molecular weights were higher than those of compounds (46) and (47).] Further elution gave the *isomer* (46) as an oil (160 mg, 11%), $\nu_{max.}$ *ca.* 3 370 (NH) and 1 740 and 1 690 cm^{-1} (CO), τ 1.78br and 1.97 (1 H, s and d, $J_{CHO,NH}$ 11.5 Hz, simplifies on addition of D_2O, CHO), 2.79br (1 H, t, disappears on addition of D_2O, CO·N*H*·CH_2), 3.3br (1 H, d, *J* 6 Hz, disappears on addition of D_2O, N*H*CHO), 5.02—5.30 (3 H, m, simplifies on addition of D_2O, H-2, -4, -5), 5.49—6.07 (8 H, m, H-3, -7, -8a, -8b, CH_2·CO·CH_2·CH_3), 6.43 (1 H, dd, $J_{6,5}$ 7, $J_{6,7}$ 3 Hz, H-6), and 8.48—8.80 (15 H, m, 4 CH_3, O·CH_2·CH_3) (Found: *m/e*, 415.172. $C_{19}H_{30}N_2O_9$ requires *M* − CH_3, 415.172).

Further elution gave the *isomer* (47) as an oil (100 mg, 7%), $\nu_{max.}$ *ca.* 3 370 (NH) and 1 740 and 1 690 cm^{-1} (CO), τ 1.76br and 1.94 (1 H, s and d, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 2.95 (2 H, m, disappears on addition of D_2O, 2 NH), 4.97 (1 H, dd, $J_{2,NH}$ 7.5, $J_{2,3}$ 5.5 Hz, simplifies on addition of D_2O, H-2), 5.00—5.30 (2 H, m, H-4, -5), 5.53—6.08 (8 H, m, H-3, -7, -8a, -8b, CH_2·CO·CH_2·CH_3), 6.44 (1 H, dd, $J_{6,5}$ 7.5, $J_{6,7}$ 3.5 Hz, H-6), and 8.46—8.80 (15 H, m, 4 CH_3, O·CH_2·CH_3) (Found: *m/e*, 415.172. $C_{19}H_{30}N_2O_9$ requires *M* − CH_3, 415.172).

Ethyl (*Ethyl* 2-*Deoxy*-2-*formylamino*-4,5:7,8-*di*-O-*isopropylidene*-α-D-manno-D-glycero-*oct*-3-*ulo*-3,6-*furanosid*)-*onate and its* L-glycero-*Isomer*, (9) *and* (10).—Compound (3) (200 mg, 0.54 mmol) was stirred in ethanol (5 ml) containing a trace of sodium ethoxide (*ca.* 2 mg) at 25 °C for 20 h. The solvent was removed and water (10 ml) containing acetic acid (5 drops) was added to the residue. The mixture was extracted with chloroform (2 × 10 ml); the combined extracts were washed with saturated aqueous sodium hydrogen carbonate (10 ml) and water (10 ml), dried ($MgSO_4$), and evaporated to give an oil. Chromatography with chloroform–ethyl acetate (3 : 2) as eluant yielded an oil which solidified. Recrystallization from ethyl acetate–hexane gave one *isomer* (9) (68 mg, 30%), m.p. 103—104°, $[\alpha]_D^{22}$ +24°, $\nu_{max.}$ 3 410 (NH) and 1 730 and 1 680 cm^{-1} (CO), *m/e* 402 (M^+ − CH_3), τ 1.86br and 2.08 (1 H, s and d, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 3.17br (1 H, d, $J_{NH,2}$ 9.5 Hz, disappears on addition of D_2O, NH), 4.82 (1 H, d, $J_{2,NH}$ 9.5 Hz, simplifies on addition of D_2O, H-2), 5.22 (1 H, dd, $J_{5,4}$ 6, $J_{5,6}$ 4 Hz, H-5), 5.47 (1 H, d, $J_{4,5}$ 6 Hz, H-4), 5.56—6.63 (8 H, m, H-6, -7, -8a, -8b, 2 O·CH_2·CH_3), 8.50, 8.62, 8.70, and 8.72 (12 H, 4s, 4 CH_3), and 8.68 and 8.90 (6 H, 2t, 2 O·CH_2·CH_3) (Found: C, 54.7; H, 7.7; N, 3.3. $C_{19}H_{31}NO_9$ requires C, 54.7; H, 7.5; N, 3.4%).

Further elution gave an oil which crystallized. Recrystallization from ethyl acetate–hexane gave the other *isomer* (10) (130 mg, 60%), m.p. 80—82°, $[\alpha]_D^{22}$ +58°, $\nu_{max.}$ 3 420 (NH) and 1 730 and 1 680 cm^{-1} (CO), *m/e* 402 (M^+ − CH_3), τ 1.74br and 2.04 (1 H, s and d, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 3.51br (1 H, d, $J_{NH,2}$ 9.5 Hz, disappears on addition of D_2O, NH), 4.63 (1 H, d, $J_{2,NH}$ 9.5 Hz, simplifies on addition of D_2O, H-2), 5.21 (1 H, dd, $J_{5,4}$ 6, $J_{5,6}$ 4 Hz, H-5), 5.48 (1 H, d, $J_{4,5}$ 6 Hz, H-4), 5.54—5.98 (5 H, m, H-7, -8a, -8b, O·CH_2·CH_3), 6.12 (1 H, dd, $J_{6,7}$ 6, $J_{6,5}$ 4 Hz, H-6), 6.41 (2 H, q, O·CH_2·CH_3), 8.55, 8.62, and 8.69 (12 H, 3s, 4 CH_3), and 8.71 and 8.86 (6 H, 2t, 2 O·CH_2·CH_3) (Found: C, 54.6; H, 7.6; N, 3.4. $C_{19}H_{31}NO_9$ requires C, 54.7; H, 7.5; N, 3.4%).

Ethyl (*Benzyl* 2-*Deoxy*-2-*formylamino*-4,5:7,8-*di*-O-*isopropylidene*-α-D-manno-D-glycero-*oct*-3-*ulo*-3,6-*furanosid*)-*onate and its* L-glycero-*Isomer*, (48) *and* (49).—Compound (3) (200 mg, 0.54 mmol) was stirred in benzyl alcohol (4 ml) containing a trace of sodium benzyl oxide (*ca.* 2 mg) at 50 °C for 4 days. The excess of benzyl alcohol was removed

in vacuo to leave an oil which was taken up in chloroform. The solution was washed (saturated aqueous sodium hydrogen carbonate), dried ($MgSO_4$), and evaporated *in vacuo*. Traces of benzyl alcohol still present in the residue were co-evaporated with water (3 × 10 ml), ethanol (2 × 10 ml), and finally chloroform (10 ml) to leave an oil which was chromatographed with chloroform–ethyl acetate (9 : 1) as eluant to give *isomer* (48) as an oil (42 mg, 16%), $[\alpha]_D^{20}$ +3°, $\nu_{max.}$ 3 410 (NH) and 1 740 and 1 690 cm^{-1} (CO), *m/e* 464 ($M^+ - CH_3$), τ 1.81br and 2.00 (1 H, d and s, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 2.71 (5 H, s, Ph), 3.12br (1 H, d, $J_{NH,2}$ 10 Hz, disappears on addition of D_2O, NH), 4.66 (1 H, d, $J_{2,NH}$ 10 Hz, simplifies on addition of D_2O, H-2), 5.16—6.22 (10 H, m, H-4, -5, -6, -7, -8a, -8b, O·CH_2·CH_3, O·CH_2·Ph), and 8.45—8.82 (15 H, m, 4 CH_3, O·CH_2·CH_3) (Found: *m/e*, 464.192. $C_{23}H_{30}NO_9$ requires $M - CH_3$, 464.192).

Further elution gave the other *isomer* (49) as an oil (155 mg, 60%), $[\alpha]_D^{20}$ +53°, $\nu_{max.}$ 3 410 (NH) and 1 740 and 1 690 cm^{-1} (CO), *m/e* 464 ($M^+ - CH_3$), τ 1.72br and 2.06 (1 H, s and d, $J_{CHO,NH}$ 12 Hz, simplifies on addition of D_2O, CHO), 3.42br (1 H, d, $J_{NH,2}$ 10 Hz, disappears on addition of D_2O, NH), 4.50 (1 H, d, $J_{2,NH}$ 10 Hz, simplifies on addition of D_2O, H-2), 5.10—6.13 (10 H, m, H-4, -5, -6, -7, -8a, -8b, O·CH_2·CH_3, O·CH_2Ph), 8.56—8.80 (15 H, 4 CH_3, O·CH_2·CH_3) (Found: *m/e* 464.192. $C_{23}H_{30}NO_9$ requires $M - CH_3$, 464.192).

Ethyl (*Methyl* 2-*Deoxy*-2-*formylamino*-4,5:7,8-*di*-O-*isopropylidene*-3-*thio*-α-D-manno-D-glycero-*oct*-3-*ulo*-3,6-*furanosid*)*onate and its* L-glycero-*Isomer* (50).—A stream of methanethiol was passed through a solution of compound (3) (371 mg, 1 mmol) in chloroform (10 ml) containing 1,5-diazabicyclo[4.3.0]non-5-ene (10 drops) at 25 °C for 1 h. The solvent was removed *in vacuo* and the residue in chloroform (50 ml) was washed with sulphuric acid (0.1N, 25 ml), saturated aqueous sodium hydrogen carbonate (25 ml), and water (25 ml), dried ($MgSO_4$), and evaporated *in vacuo* to give a pale yellow oil. Chromatography with ethyl acetate as eluant gave a mixture of thio-compounds (50) as an oil (410 mg, 98%), $\nu_{max.}$ 3 400 (NH) and 1 740 and 1 690 cm^{-1} (CO), *m/e* 404 ($M^+ - CH_3$), τ 1.78—2.08 (1 H, m, simplifies on addition of D_2O, CHO), 3.16br and 3.56br (1 H, 2d, $J_{NH,2}$ 9 Hz, disappears on addition of D_2O, NH), 4.57 and 4.74 (1 H, 2d, $J_{2,NH}$ 9 Hz simplifies on addition of D_2O, H-2), 5.18 (1 H, dd, $J_{5,4}$ 6, $J_{5,6}$ 4 Hz, H-5), 5.44 (1 H, d, $J_{4,5}$ 6 Hz, H-4), *ca.* 5.44—6.13 (6 H, m, H-6, -7, -8a, -8b, O·CH_2·CH_3), 7.95—8.10 (3 H, m, SCH_3), and 8.46—8.80 (15 H, m, 4 CH_3, O·CH_2·CH_3) (Found: *m/e*, 404.136. $C_{17}H_{26}NO_8S$ requires $M - CH_3$, 404.138).

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