A Deoxyketose *via* Two-Carbon Chain Extension of Mannose

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Reaction of D-mannose with nitroethane gives an epimerically pure sodium 1,2-dideoxy-2-nitrooctitol which on hydrolysis gives 1-deoxy-D-*glycero*-D-*galacto*-octulose (**3**). The same deoxyoctulose was prepared by addition of ethynylmagnesium bromide to di-*O*-isopropylidene mannose followed by mercury-catalyzed hydration of the resultant 4,5:7,8-di-*O*-isopropylidene-1-octyne-D-*glycero*-D-*galacto*-3,4,5,6,7,8-hexol (**5a**). The absolute stereochemistry of these compounds was proved by reduction of the octyne **5a** to the octene **6a** and subsequent ozonolysis of the octene to give the known D-*glycero*-D-*galacto*-heptonolactone. The new deoxyketose has optical rotation properties expected of a galacto rather than a talo homomorph which might possibly have been produced in the asymmetric syntheses.

Deoxyketoses have been prepared in several different ways,[2] but the most frequently reported route involves the addition of diazomethane to an acetylated aldonic acid chloride.[3] The deoxyketoses (*e.g.*, **3**) can be viewed as homomorphs of aldopyranoses in which the anomeric hydrogen is replaced by the larger, but still nonpolar, methyl group. This study involves two methods of preparation of a galacto homomorph, the assignment of its stereochemistry, and the comparison of its optical rotation and α/β anomer ratio to its known homomorphs and other 1-deoxyketoses. The methods involve adding two carbons at a time using either nitroethane or acetylene to extend the carbon chain. Of the two routes, the nitroethane addition is the superior preparative method. Acetylene chemistry has been used to synthesize sugars *de novo*[4] and to prepare alkyne polyols.[5] Nitroethane has been added to dialdose derivatives to give a *C*-methyl inositol[6] and an 8-deoxyoctose.[7]

Success of the nitroalkane–aldose addition[8,9] as a preparative method often depends upon product precipitation to drive the equilibrium. The product of addition of sodium ethane nitronate to mannose is insoluble in methanol and provides a convenient route to 1-deoxy-D-*glycero*-D-*galacto*-octulose (**3**). Precipitation of sodium 1,2-dideoxy-2-nitrooctitol is nearly quantitative after about 5 days. The nmr spectrum of the sodium salt contains a single, unsplit *C*-methyl resonance (τ 8.05), consistent with the presence of only one of the possible C-3 epimers. Neutralization of the sodium salt produces two readily separable diastereomeric nitrooctitols **1** and **2** in nearly equal yield. When the purified high-melting isomer was converted into its salt and reneutralized, the same ratio of high-melting to low-melting diastereomer was produced, as would be expected if the nitrooctitols differ in configuration at the nitro-bearing carbon, C-2, but not at C-3. Examination of the mother liquor from crystallization of these two C-2 epimers by nmr failed to show the presence of *C*-methyl resonances ascribable to the possible C-3 epimers.

The high stereospecificity of this aldose-nitroethane addition is in contrast to the generally low stereospecificity in additions involving nitromethane[10] and makes possible a very simple preparation of 1-deoxy-D-*glycero*-D-*galacto*-octulose without the isolation of nitroalditol isomers necessary in homologations with nitromethane. Deoxyoctulose was prepared from mannose in 55% overall yield *via* the Nef reaction. The crystalline deoxyoctulose exhibits mutarotation and a strongly positive equilibrium optical rotation. The deoxyoctulose can be precipitated quantitatively from cold, aqueous solutions as its phenylhydrazone. The phenylhydrazone is so insoluble, even at reflux, that attempts to prepare its osazone gave only the hydrazone discolored pale yellow, by a small amount of osazone, or tar on extended heating. In this respect the deoxyoctulose resembles mannose, the sugar from which it was prepared. Mannose and the deoxyketose are incompletely resolved in most of the common chromatographic systems for sugars but are readily resolved when the chromatographic paper is impregnated with sodium borate. The formation of up to three cis borate esters of the deoxypyranulose, but only a monoborate ester of mannopyranulose may account for this separation and for the fact that the deoxyoctulose migrated 1.4 times as far toward the anode as did mannose on electrophoresis in borate buffer. The steric requirements for bridging vicinal hydroxyls by borate esters is similar to that for bridging by ketals. The deoxyoctulose gives the triketal **8**. The nmr spectrum of tri-*O*-isopropylidene deoxyoctulose clearly shows that it is present in the twist–boat conformation (J_{34} = 2.6 hz) which has been found for several di-*O*-isopropylidene derivatives of galacto homomorphs.[11]

A chemical proof of configuration of the deoxyoctulose (Scheme I) was provided by relating the new center of asymmetry produced in the mannose–nitroethane addition to the new center created in the reaction of di-*O*-isopropylidene mannose (**4**) and ethynylmagnesium bromide to give 4,5:7,8-di-*O*-isopropylidene-1-octyne-D-*glycero*-D-*galacto*-3,4,5,6,7,8-hexol (**5a**). The fact that the configurations of the new centers produced in these two different reactions of mannose is the same was demonstrated by conversion of **5a** to the deoxyoctulose **3** by hydrolysis and mercury-catalyzed hydration of the acetylene.

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(2) M. L. Wolfrom, J. D. Crum, J. B. Miller, and D. I. Weisblat, *J. Amer. Chem. Soc.*, **81**, 243 (1952); B. Coxon and H. G. Fletcher, Jr., *ibid.*, **86**, 922 (1964); A. Ishizu, B. Lindberg, and O. Theander, *Carbohyd. Res.*, **5**, 329 (1967).

(3) M. L. Wolfrom and R. B. Bennett, *J. Org. Chem.*, **30**, 458 (1965).

(4) R. Lespieau, *Advan. Carbohyd. Chem.*, **2**, 107 (1946); M. M. Fraser and R. A. Raphael, *J. Chem. Soc.*, 4280 (1955).

(5) D. Horton, J. B. Hughes, and J. K. Thomson, *J. Org. Chem.*, **33**, 728 (1968).

(6) F. W. Lichtenthaler and H. K. Yahya, *Carbohyd. Res.*, **5**, 485 (1967).

(7) D. G. Lance, W. A. Szarek, J. K. N. Jones, and G. B. Howarth, *Can. J. Chem.*, **47**, 2871 (1969).

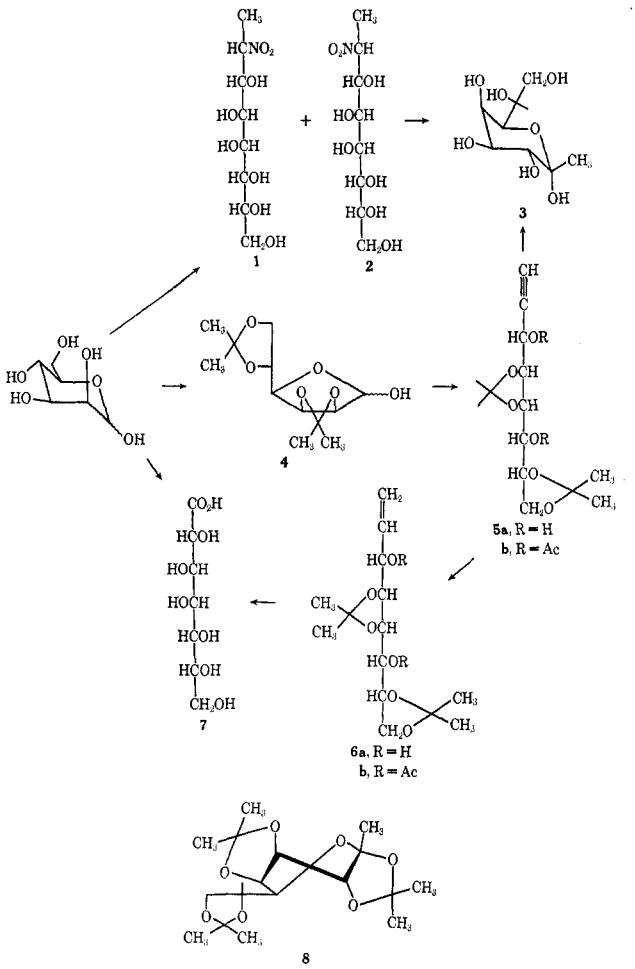
(8) J. C. Sowden, *Advan. Carbohyd. Chem.*, **6**, 291 (1951).

(9) H. H. Baer, *ibid.*, **24**, 67 (1969).

(10) J. C. Sowden and H. O. L. Fischer, *J. Amer. Chem. Soc.*, **73**, 4662 (1951).

(11) C. Cone and L. Hough, *Carbohyd. Res.*, **1**, 1 (1965).

SCHEME I



The absolute configuration created in the two reactions was determined by conversion of **5a** into a known heptonic acid. Reduction of **5b** with lithium aluminum hydride gave 4,5:7,8-di-*O*-isopropylidene-1-octene-D-*glycero*-D-*galacto*-3,4,5,6,7,8-hexol (**6a**) which was acetylated, ozonized, and hydrolyzed to D-*glycero*-D-*galacto*-heptonic acid (**7**), isolated as its lactone. The lactone and its derived phenylhydrazide were identical by chromatography, mixture melting point, and optical rotatory dispersion with authentic lactone and phenylhydrazide prepared by hydrogen cyanide addition to mannose.[12]

The ozonolyses of **6a** and **6b** were not simple reactions. Two other products having higher R_f values than the heptonic acid were present. Ozonolysis of allylic alcohols and esters is known to give both the normal products and abnormal products.[13] Direct ozonolysis of the acetylenes **5a** and **5b** as well as of **6a** gave more of the abnormal products and insufficient heptonic acid for characterization by derivatization or optical rotation.

An attempt was also made to obtain the heptonic acid directly from the deoxyoctulose by haloform degradation. However, the maximum yield of iodoform (15%) indicates that there is a competing reaction, possibly iodination at C-3 with preceding loss of asymmetry at the center under stereochemical investigation. Other 1-deoxyketoses give positive iodoform tests but no yields of iodoform were reported.[14]

The configurations of anomeric centers of ketoses are not readily proven by rigorous methods. The anomeric centers of ketoses have been assigned by assuming that an anomer of high optical rotation is an α-pyranose and that one of low rotation is a β-pyranose in analogy to the well-tested rules for aldoses. Three assumptions involved in applying the aldose optical rotation–structure relationship to ketoses are that the replacement of the anomeric hydrogen by aliphatic carbon has negligible effect on the optical rotation of a given conformer, the replacement does not greatly alter the *CA–CE* conformational equilibrium, and the crystalline and solution structures are pyranoses, not furanoses. The assignment of anomeric configuration of ketoses on the basis of optical rotation lacks rigor in that the validity of these assumptions has not yet been widely tested and in no case are both crystalline ketopyranose anomers known. Despite these reservations the anomeric assignments by optical rotation have been confirmed crystallographically in three cases. Crystalline β-D-fructopyranose, α-L-sorbopyranose, and α-D-tagatopyranose all are anomers in conformations with axial anomeric hydroxyl, equatorial C_1, and not more than one other hydroxyl axial.[15] Since these ketoses all exhibit small or no mutarotation, it is probable that the same anomers and conformations dominate in aqueous solution. An empirical nmr method has also been used to infer that L-sorbose, D-tagatose, and D-*gluco*-heptulose are largely present in dimethyl sulfoxide as the α anomers in *CA* conformation.[16] It appears that the dominant ketopyranose anomer and conformer in solution is likely to be the one in which C_1 is equatorial and the maximum number of nonanomeric hydroxyls are equatorial. In dimethyl sulfoxide or water 1-deoxy-D-*glycero*-D-*galacto*-octulose is overwhelmingly in a single tautomeric form at equilibrium (single *C*-methyl signal). Since freshly dissolved deoxyoctulose mutarotates toward a substantially more positive value in water and in dimethyl sulfoxide, the solution anomer is probably α-pyranose in *CA* conformation (**3**). The low rotation of the crystalline deoxyoctulose, while suggestive of a β-pyranose, cannot exclude the possibility that the crystalline form is a furanose or septanose. Indeed, the number of transient *C*-methyl singlets in the nmr spectrum during mutarotation (up to four) requires invoking furanose, septanose, or acyclic forms, at least as intermediates.

The importance of series of pyranose homomorphs in relating chemical reactivity, enzymatic specificity, and physical properties of aldoses has been recognized for some time.[17] Among physical properties optical rotation is a convenient measure by which to compare shapes. The magnitude of aldose mutarotation values is determined largely by the stereochemistry at the first four centers of asymmetry, C_2 through C_5. This is because those centers largely determine the preferred conformation of the pyranose ring, the α/β anomer ratio, and the asymmetry around the lactol oxygen. Centers

(12) G. Pierce, *J. Biol. Chem.*, **23**, 333 (1916); E. Fischer and F. Passmore, *Ber.*, **23**, 2226 (1890).

(13) W. G. Young, A. C. McKinnis, I. D. Webb, and J. D. Roberts, *J. Amer. Chem. Soc.*, **68**, 293 (1946).

(14) M. L. Wolfrom, D. I. Weisblat, W. H. Zophy, and S. W. Waisbrot, *ibid.*, **63**, 201 (1941); M. L. Wolfrom and R. L. Brown, *ibid.*, **65**, 1516 (1943).

(15) S. Takagi and R. D. Rosenstein, *Carbohyd. Res.*, **11**, 156 (1969).

(16) J. C. Jochimo, G. Taigel, A. Sediger, P. Lutz, and H. E. Drisen, *Tetrahedron Lett.*, 4363 (1967).

(17) C. S. Hudson, *J. Amer. Chem. Soc.*, **57**, 2100 (1935); **59**, 548 (1937). H. S. Isbell, *J. Res. Nat. Bur. Stand.*, **18**, 505 (1937).

of asymmetry at C_6 and higher in heptoses, octoses, and nonoses have little effect on the equilibrium rotation value because the variety of conformations adopted by the flexible side chain tends to have self-cancelling effects on conformation, α/β anomer ratio, and optical rotation.[18] An example of the importance of the stereochemistry at the first four centers can be seen by comparing the mutarotation values of galacto homomorphs to those of talo homomorphs (Table I).

TABLE I

MOLECULAR ROTATIONS OF *galacto*- AND *talo*-ALDOSES[a]

Galacto homomorphs	[φ]	Talo homomorphs	[φ]
D-Galactose	14,500	D-Talose	3780
D-*glycero*-D-*galacto*-Heptose[b]	13,600	D-*glycero*-D-*talo*-Heptose[b]	3150
L-*glycero*-D-*galacto*-Heptose[c]	13,600	L-*glycero*-D-*talo*-Heptose[i]	3570
D-*erythro*-D-*galacto*-Octose[d]	15,300		
L-*erythro*-D-*galacto*-Octose[e]	14,800		
L-*threo*-D-*galacto*-Octose[f]	13,400	L-*erythro*-D-*talo*-Octose[j]	1560
L-*arabino*-D-*galacto*-Nonose[g]	12,100	L-*arabino*-D-*talo*-Nonose[g]	2880
D-*gluco*-D-*galacto*-Decose[h]	15,000		

[a] Some values derived from enantiomers. [b] H. S. Isbell, *J. Res. Nat. Bur. Stand.*, **20**, 97 (1938). [c] F. B. La Forge, *J. Biol. Chem.*, **41**, 251 (1920). [d] A. J. Charlson and N. K. Richtmyer, *J. Amer. Chem. Soc.*, **82**, 3428 (1960). [e] W. D. Maclay, R. M. Hann, and C. S. Hudson, **60**, 1035 (1938); R. M. Hann, A. T. Merrill, and C. S. Hudson, *ibid.*, **66**, 1912 (1944). [f] N. K. Kochetkov and B. A. Dmitriev, *Bull. Acad. Sci. USSR*, 1367 (1965). [g] J. C. Sowden and D. R. Strobach, *J. Amer. Chem. Soc.*, **82**, 956 (1960). [h] C. S. Hudson, *Advan. Carbohyd. Chem.*, **1**, 1 (1945). Stereochemical assignment based on optical rotation magnitude, see p 29. [i] H. S. Isbell, *J. Res. Nat. Bur. Stand.*, **19**, 639 (1937). [j] A. T. Merrill, R. M. Hann, and C. S. Hudson, *J. Amer. Chem. Soc.*, **65**, 994 (1943).

Similar structure–rotation relationships apply to ketoses (Table II). The mutarotation value appears to

TABLE II

MOLECULAR ROTATIONS OF *galacto*- AND *talo*-KETOSES

Ketose	[φ]D
D-*galacto*-Heptulose[a]	16,700
D-*glycero*-D-*galacto*-Octulose[b]	15,800
L-*glycero*-D-*galacto*-Octulose[c]	13,700
L-*erythro*-D-*galacto*-Nonulose[d]	10,000
D-*talo*-Heptulose[e]	2,700

[a] J. K. N. Jones and N. K. Matheson, *Can. J. Chem.*, **37**, 1754 (1959). [b] M. L. Wolfrom and P. W. Cooper, *J. Amer. Chem. Soc.*, **72**, 1345 (9950). [c] H. H. Sephton and N. K. Richtmyer, *J. Org. Chem.*, **28**, 1691 (1963). [d] H. H. Sephton and N. K. Richtmyer, *Carbohyd. Research*, **2**, 289 (1966). [e] J. W. Pratt and N. K. Richtmyer, *J. Amer. Chem. Soc.*, **77**, 6326 (1955); J. C. Sowden and D. R. Strobach, *ibid.*, **80**, 2532 (1958).

be little affected by replacement of a side chain hydroxyl by hydrogen (Table III). Therefore, rotations of ketoses and 1-deoxyketoses may be compared freely. The *galacto*-ketoses have high molecular rotation as do *galacto*-aldoses. The single *talo*-ketose has the low rotation typical of *talo*-aldoses. The large positive equilibrium rotation value of the newly prepared deoxyoctulose, [α]D 87 (*c* 1,H_2O, final), is consistent with the chemically established fact that it is 1-deoxy-D-*glycero*-D-*galacto*-octulose (**3**) rather than the talo epimer.

(18) W. J. Kauzmann, J. E. Walter, and H. Eyring, *Chem. Rev.*, **26**, 378 (1940).

TABLE III

MOLECULAR ROTATIONS OF PAIRS OF KETOSES AND 1-DEOXYKETOSES

Ketose and 1-deoxyketose pairs	[φ]D
D-*arabino*-Hexulose (fructose)	−16,700
1-Deoxy-D-*arabino*-hexulose[a]	−14,800
D-*ribo*-Hexulose (psicose)	560
1-Deoxy-D-*ribo*-hexulose[b]	250
D-*lyxo*-Hexulose	−180
1-Deoxy-D-*lyxo*-hexulose[c]	−2,500
D-*galacto*-Heptulose[d]	16,700
1-Deoxy-D-*galacto*-heptulose[e]	12,500
D-*glycero*-D-*gulo*-Octulose[f]	7,500
1-Deoxy-D-*glycero*-D-*gulo*-octulose[g]	7,600
D-*glycero*-D-*galacto*-Octulose[h]	13,700
1-Deoxy-D-*glycero*-D-*galacto*-octulose	19,700

[a] A. Ishizu, B. Lindberg, and O. Theander, *Carbohyd. Res.*, **5**, 329 (1967). [b] M. L. Wolfrom, A. Thompson, and E. F. Evans, *J. Amer. Chem. Soc.*, **67**, 1793 (1945). [c] M. L. Wolfrom and R. B. Bennett, *J. Org. Chem.*, **30**, 1284 (1965). [d] J. K. N. Jones and N. K. Matheson, *Can. J. Chem.*, **37**, 1754 (1959). [e] B. Coxon and H. G. Fletcher, *J. Amer. Chem. Soc.*, **86**, 922 (1964). [f] N. K. Richtmyer and T. S. Bodenheim, *J. Org. Chem.*, **27**, 1892 (1962). [g] P. A. J. Gorin and T. Ishikawa, *Can. J. Chem.*, **45**, 521 (1966). [h] M. L. Wolfrom and P. W. Cooper, *J. Amer. Chem. Soc.*, **72**, 1345 (1950); J. K. N. Jones and H. H. Sephton, *Can. J. Chem.*, **38**, 753 (1960).

Experimental Section

General Procedures.—Paper chromatography was carried out on Whatman 3 MM paper. In system A the chromatographic solvent was isopropyl alcohol–water 4:1. For system B the solvent was *n*-butyl alcohol–pyridine–water 6:4:3 and the paper had been previously impregnated with sodium borate by dipping in 0.025 *M* sodium tetraborate and air drying. Migration ratios are expressed relative to mannose($R_{mannose}$).

Nmr chemical shifts were measured in D_2O with respect to internal sodium dimethylsilapentane sulfonate and in organic solvents with respect to internal TMS on Varian A-60 and HA-100 spectrometers. Optical rotations were measured with a Cary 60 spectropolarimeter.

1-Deoxy-D-*glycero*-D-*galacto*-octulose (3).—A cooled solution of 18 g (0.45 mol) of sodium hydroxide in 20 ml of water was mixed with 125 ml of methanol. The resultant solution was added to a stirred suspension of 40 g (0.22 mol) of D-mannose in 175 ml of methanol and 100 ml of nitroethane. The suspended mannose dissolved after addition of the sodium hydroxide. Precipitation began after 1 hr. After 1 week 60 g of crude nitrooctitol salt, mp 135–140° dec, was collected.

A filtered solution of 30 g (0.11 mol) of crude sodium nitrooctitol in 100 ml of water was added dropwise at 0° to a stirred solution of 13.4 ml (0.25 mol) of concentrated sulfuric acid in 10 ml of water. After nitrous oxide evolution ceased, the solution was passed through 600 ml of anion exchange resin (Bio Rad AG 3-X4, hydroxide form) and 600 ml of cation exchange resin (Dowex 50, acid form). The effluent was concentrated, neutralized with a small amount of Dowex 1, carbonate form, and further concentrated to an oil which was crystallized from ethanol giving 13.6 g (55% yield based on mannose) of 1-deoxy-D-*glycero*-D-*galacto*-octulose: mp 149–151°, $[\alpha]^{23}D$ 87° (water, final); $R_{mannose}$ 0.95 (system A), 0.47 (system B). The absence of mannose was confirmed by paper chromatography in system B.

Anal. Calcd for $C_8H_{16}O_7$: C, 42.89; H, 7.19. Found: C, 42.73; H, 7.02.

The 1-deoxy-D-*glycero*-D-*galacto*-octulose phenylhydrazone, mp 204–206°, was prepared in the same manner as mannose phenylhydrazone.

Anal. Calcd for $C_{14}H_{22}N_2O_6$: C, 53.50; H, 7.06; N, 8.91. Found: C, 53.27; H, 7.01; N, 8.74.

2-Methyl-3-(D-*manno*-pentahydroxypentyl)quinoxaline.—A solution of 450 mg (2 mmol) of 1-deoxyoctulose, 116 mg (1 mmol) of *o*-phenylenediamine, 0.2 ml (4 mmol) of hydrazine hydrate, 0.68 ml of acetic acid, and 3 ml of water was heated at reflux under nitrogen for 8 hr. Recrystallization of the precipitate from ethanol gave quinoxaline, mp 233–234°.

Anal. Calcd for $C_{14}H_{18}N_2O_5$: C, 57.14; H, 6.16; N, 9.52. Found: C, 57.26; H, 6.07; N, 9.70.

Epimeric 1,2-Dideoxy-2-nitrooctitols 1 and 2.—A precipitate of epimeric nitrooctitols was obtained by acidifying a concentrated solution of the sodium salt with acetic acid. The less soluble epimer was recrystallized from water until epimerically pure by nmr: mp 178–180°; $[\alpha]^{25}_{589}$ 17.8° (*c* 0.8, H_2O); $R_{mannose}$ 1.45 (system A); nmr (D_2O) τ 8.38 (d, 3, J = 7 Hz, CCH_3).

Anal. Calcd for $C_8H_{17}NO_8$: C, 37.65; H, 6.71; N, 5.49. Found: C, 37.86; H, 6.69; N, 5.64.

The more soluble isomer was recrystallized from ethanol until epimerically pure by nmr: mp 189–192°; $[\alpha]^{25}_{589}$ 7.5° (*c* 1.0, H_2O); $R_{mannose}$ 1.45 (system A); nmr (D_2O) τ 8.45 (d, 3, J = 7 Hz, CCH_3).

Anal. Calcd for $C_8H_{17}NO_8$: C, 37.65; H, 6.71; N, 5.49. Found: C, 37.83; H, 6.85; N, 5.10.

3,6-Di-*O*-acetyl-4,5:7,8-di-*O*-isopropylidene-1-octyne-D-glycero-D-*galacto*-3,4,5,6,7,8-hexol (5b).—Ethynylmagnesium bromide was prepared by the Grignard exchange reaction with 40 g of ethyl bromide and 10 g of magnesium in 300 ml of tetrahydrofuran. A solution of 10 g of di-*O*-isopropylidene mannose in 50 ml of tetrahydrofuran was added dropwise to the ethynylmagnesium bromide. After 1.5 hr solvent was removed. The residual oil was acetylated by treatment with acetic anhydride in pyridine. The acetylation solution was diluted with water and extracted with ether. Ether was removed and 11.5 g of residual syrup was chromatographed over 45 g of alumina with petroleum ether as eluent giving 7.5 g (68%) of crystalline **5b**: mp 80°; ir (KBr) 3260 (C≡CH), 1740 cm^{-1} (C=O); nmr (CCl_4) τ 7.68 (d, 1, J_{13} = 2 Hz, C≡CH).

Anal. Calcd for $C_{18}H_{26}O_8$: C, 58.49; H, 7.15. Found: C, 58.37; H, 7.08.

Compound **5b** was deacetylated by heating with aqueous sodium carbonate for 2 hr followed by extraction with ether and recrystallization of the material in the ether layer from benzene–petroleum ether to give **5a**, mp 74°.

Anal. Calcd for $C_{14}H_{22}O_6$: C, 58.73; H, 7.74. Found: C, 58.92; H, 7.83.

Deoxyoctulose by Hydration of 5a.—A solution of 1 g of **5a** and 2 g of mercuric acetate in 100 ml of ethyl acetate was heated at reflux for 20 hr. Mercury was removed by saturating the solution with hydrogen sulfide. Solvent was removed from the filtered solution. The residual oil was treated with 10% aqueous potassium carbonate and extracted into ether. Ether was removed and the residual oil was warmed with 10% acetic acid. The water was extracted with ether and the aqueous layer was concentrated to give a white solid which, after recrystallization from ethanol, gave 300 mg of deoxyoctulose: mp 149–150°, mmp 148–149° with deoxyoctulose prepared by the nitroethane method; $R_{mannose}$ 0.95 (system A); phenylhydrazone derivative mp 208–210°; mmp 207–209° with phenylhydrazone derived from deoxyoctulose prepared by the nitroethane method.

3,6-Di-*O*-acetyl-4,5:7,8-di-*O*-isopropylidene-1-octene-D-*glycero*-D-*galacto*-3,4,5,6,7,8-hexol (6b).—A mixture of 1.8 g of lithium aluminum hydride and 2.0 g of octynitol **5b** in 150 ml of tetrahydrofuran was heated at reflux 12 hr. Excess hydride was destroyed by addition of aqueous ammonium chloride. Solvent was removed from the ether layer and the resultant syrup was treated with pyridine and acetic anhydride. On removal of solvent 1.8 g of syrupy **6b** was obtained: ir no acetylenic CH; nmr ($CDCl_3$) τ 4.1–5.0 complex, C=CH), no acetylenic proton.

Ozonolysis of 6b.—Ozone was passed through a cooled solution of 1.8 g of octenitol **6b** in CCl_4 for 1 hr. The solution was then poured into cold water. After 1 hr 0.8 g of sodium hydroxide and 2.9 g of silver oxide were added and the mixture was heated at reflux for 2.5 hr. The cooled, filtered solution was acidified with acetic acid and extracted with ether. The residue obtained by removal of water from the aqueous layer was extracted with ethanol. Paper chromatography of the ethanolic extract in system A showed Tollens positive spots at R_f 0.40 (major), 0.43 (minor), and 0.47 (minor). Authentic D-*glycero*-D-*galacto*-heptonolactone[8] had R_f 0.40. Concentration of the ethanolic solution and recrystallization from ethanol gave 85 mg of crystalline lactone: mp 149°; levorotatory in water; authentic D-*glycero*-D-*galacto*-heptonolactone, mp 148–150°, levorotatory; mmp 148–149°. Both lactones were converted to phenylhydrazides. Authentic D-*glycero*-D-*galacto*-heptonic acid phenylhydrazide:[19] mp 220–223°; $[\alpha]^{23}_{589}$ 24° (*c* 0.28, H_2O). Phenylhydrazide obtained by ozonolysis: mp 218–219°; $[\alpha]^{23}_{589}$ 29° (*c* 0.23, H_2O); mmp 218–220°.

1-Deoxy-2,3:4,5:7,8-tri-*O*-isopropylidene-D-*glycero*-D-*galacto*-octulose (8).—A solution of 1 g of phosphorus pentoxide in 2 g of 85% phosphoric acid was added to a suspension of 4.5 g of 1-deoxy-D-*glycero*-D-*galacto*-octulose in 150 ml of acetone. Then 6 g of zinc chloride was added and the mixture was stirred at room temperature for 12 hr. The solution was made basic with saturated aqueous sodium bicarbonate. Precipitated zinc carbonate was filtered off and acetone was distilled from the filtrate. The residue was recrystallized from benzene–petroleum ether to give 5.9 g (84%) of triisopropylidene deoxyoctulose **8**: mp 81°; ir no hydroxyl; nmr ($CDCl_3$) τ 6.35 (H-6, J_{56} = 1.8, J_{67} = 8.5 Hz), 5.98 (multiplet, H-8), 5.88 (H-3, J_{34} = 2.6 Hz), 5.77 (H-7, J_{78} = 5 Hz), 5.60 (H-5, J_{45} = 8.0 Hz), 5.35 (H-4).

Anal. Calcd for $C_{17}H_{28}O_7$: C, 59.25; H, 8.19. Found: C, 59.44; H, 8.25.

Registry No.—**1**, 31024-96-1; **2**, 31024-97-2; **3**, 31107-18-3; **3** phenylhydrazone, 31024-98-3; **5a**, 31024-99-4; **5b**, 31107-19-4; **6b**, 31025-00-0; **8**, 31025-01-1; D-mannose, 3458-28-4; 2-methyl-3-(D-*manno*-pentahydroxypentyl)quinoxaline, 31025-02-2.

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(19) E. Fischer and F. Passmore, *Ber.*, **22**, 2728 (1889).