crystallization to give, after recrystallization from methanol, 280 mg (84%) of **34**: mp 188–190°; $[\alpha]^{20}D$ −9°(*c* 1, MeOH); nmr ($CDCl_3$) τ 4.01 (d, 1, $J_{1',2'}$ = 9.5 Hz, H-1'), 7.93 and 8.04 (s, 3,2'- and 4'-OAc), 8.18 (s, 3, NHAc), 8.27 (s, 3,3'-CH_3).

Anal. Calcd for $C_{36}H_{37}N_3O_9$: C, 65.94; H, 5.69; N, 6.41. Found: C, 65.84; H, 5.49; N, 6.48.

***C*-Methyl-Branched Cyclanols. 1*r*-Methylcyclohexane-1,2*c*,6*c*-triol.**—To an ethereal solution of methylmagnesium iodide, prepared from 3.4 g of magnesium and methyl iodide (11.4 ml) in ether (80 ml), was added a solution of 4.3 g of 1,3-diacetoxycyclohexan-2-one[42] in chloroform (140 ml). The mixture was refluxed for 30 min and subsequently stirred into an excess of 2 *N* H_2SO_4. After evaporation of the organic solvents and addition of the calculated amount of silver carbonate, the mixture was neutralized with 1 *N* sodium hydroxide (pH 7), filtered to remove the silver iodide formed, and evaporated to dryness. The residue was extracted with ether overnight, to give, after evaporation and recrystallization from ethyl acetate, 900 mg (31%) of a product melting at 122–124°.

Anal. Calcd for $C_7H_{14}O_3$: C, 57.51; H, 9.65. Found: C, 57.43; H, 9.68.

Tri-*O*-acetyl-1*r*-methylcyclohexane-1,2*c*,6*c*-triol (39).—To a mixture of 5 ml of acetic anhydride and 3 drops of concentrated H_2SO_4 was added 300 mg of 1*r*-methylcyclohexane-1,2*c*,6*c*-triol. After 4 hr at ambient temperature, the solution was stirred into ice–water, which was repeatedly extracted with chloroform. The extracts were washed with $NaHCO_3$ solution, dried (Na_2SO_4), and evaporated to dryness. Recrystallization of the residue from ethyl acetate afforded 240 mg (45%) of **39** as colorless prisms, mp 102–103°; for nmr *cf.* Table II.

Anal. Calcd for $C_{13}H_{20}O_6$: C, 57.34; H, 7.40. Found: C, 57.22; H, 7.30.

1-Acetamido-2*c*,6*c*-dimethanesulfonyloxy-1*r*-methylcyclohexane (36).—To a cooled solution of 22.2 g (0.12 mol) of the *N*-acetate **35**[21] in pyridine (300 ml) was added gradually 40 ml (0.52 mol) of methanesulfonyl chloride with stirring. The mixture was stored at 0° for 20 hr, then concentrated to a crystalline solid *in vacuo* (finally 0.1 mm), and triturated with ice–water. The product was filtered off, thoroughly washed with acetone–methanol (2:1), and recrystallized from water–methanol (10:1) with the addition of activated carbon, to give 34.0 g (81%) of **36** as colorless crystals: mp 147°; nmr (DMSO-d_6) τ 2.30 (s, 1, NH), 4.52 (q, 2, $J_{a,a}$ = 10 and $J_{a,e}$ = 5 Hz, H-2 and H-6), 6.92 (s, 6, 2- and 6-OMs), 8.18 (s, 3, NHAc), 8.87 (s, 3, 1-CH_3).

Anal. Calcd for $C_{11}H_{21}NO_7S_2$: C, 38.47; H, 6.16; N, 4.08. Found: C, 38.35; H, 6.13; N, 4.05.

1-Acetamido-2*t*,6*t*-diacetoxy-1*r*-methylcyclohexane (37).—The dimesylate **36** (3.0 g) was refluxed for 17 hr with sodium acetate (3.6 g) in 150 ml of 2-methoxyethanol–water (9:1), and then concentrated. The resulting residue was extracted several times with hot acetone and the combined extracts were then evaporated to dryness to give a pale yellow sirup, which is acetylated by treatment with acetic anhydride (5 ml) and pyridine (30 ml) at room temperature overnight. The mixture was concentrated to a semicrystalline solid, which, after trituration with water, was filtered off and recrystallized twice from water to yield 1.42 g (60%) of **37** as colorless crystals: mp 156–158°; nmr ($CDCl_3$) τ 4.13 (s, 1, NH), 4.50 (m, 2, H-2 and H-6); nmr (DMSO-d_6) 2.67 (s, 1, NH), 4.70 (m, 2, H-2 and H-6); for other data *cf.* Table III.

Anal. Calcd for $C_{13}H_{21}NO_5$: C, 57.55; H, 7.80; N, 5.16. Found: C, 57.50; H, 7.71; N, 5.17.

Registry No.—**4**, 13184-57-1; **5**, 13184-60-6; **6**, 13184-59-3; **7**, 34280-68-7; **8**, 13184-58-2; **9**, 13184-65-1; **10**, 13184-64-0; **11**, 34280-72-3; **12**, 13184-61-7; **13**, 34280-74-5; **14**, 34280-75-6; **15**, 34280-76-7; **16**, 13184-63-9; **17**, 34280-78-9; **18**, 34297-61-5; **19**, 34280-79-0; **20**, 34297-62-6; **21**, 34280-80-3; **22**, 34280-81-4; **23**, 34280-82-5; **24**, 34280-83-6; **25**, 34280-84-7; **26**, 34280-85-8; **27**, 34280-86-9; **28**, 34280-87-0; **29**, 34280-88-1; **30**, 34280-89-2; **31**, 34297-63-7; **32**, 34280-90-5; **33**, 34280-91-6; **34**, 34280-92-7; **36**, 34280-93-8; **37**, 34280-94-9; **39**, 34280-95-0; 1*r*-methylcyclohexane-1,2*c*,6*c*-triol, 34280-96-1.

(42) G. W. Cavill and D. H. Solomon, *J. Chem. Soc.*, 4426 (1955).

C → O Migration of an Ethoxycarbonyl Group[1,2]

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The first example of a base-catalyzed C → O ethoxycarbonyl shift is described, occurring during the reaction of dialdehyde **1** (obtained from methyl α-D-glucopyranoside by periodation) with ethyl nitroacetate in the presence of base. The reaction products were proved to be methyl 3-deoxy-6-*O*-ethoxycarbonyl-3-nitro-α-D-hexosides of gluco (**8**) and manno configuration by preparation of a number of derivatives **9**–**12** by hydrolysis of the ethoxycarbonyl group in **9** and **12** to give known glucosides and by nmr and mass spectral data. Mechanistic aspects of this C → O migration are discussed.

While the occurrence of C → C migrations of alkoxycarbonyl groups is exceedingly well documented in the literature,[3] only one example each of an N → O[4] and of an O → O alkoxycarbonyl shift[5] has been disclosed. We now wish to report on yet another type, namely, on the first example of a C → O migration of an ethoxycarbonyl group. This rearrangement took place in a product formed from reaction of ethyl nitroacetate with a 1,5-dialdehyde.

The reaction of 2-*O*-(*S*-methoxyformyl)methyl-(*R*)-glyceraldehyde[6] (readily accessible from methyl α-D-glucoside by periodate oxidation) with ethyl nitroacetate in aqueous ethanol at pH 8.6 has been reported to give a substance to which the 1,4-dioxane structure **2** was assigned. Though structure **2** was further supported by derivatives **3**–**5**, and though some nmr data were cited as proof,[7] these findings neither explain why addition should preferentially occur at one aldehyde function nor why two pentose dialdehydes,[8] differing from **1** only in the absence of a hydroxymethyl sub-

(1) Nitromethane Condensation with Dialdehydes. XIX. Paper XVIII: F. W. Lichtenthaler and H. Zinke, *J. Org. Chem.*, **37**, 1612 (1972).

(2) (a) Taken in part from the doctoral dissertation of G. Bambach, submitted to the Technische Hochschule Darmstadt, Oct 1971. (b) Financial support of this work by the Deutsche Forschungsgemeinschaft and the Fonds der Chemischen Industrie is gratefully acknowledged.

(3) R. M. Acheson, *Accounts Chem. Res.*, **4**, 177 (1971).

(4) J. H. Ransom, *Chem. Ber.*, **33**, 199 (1900).

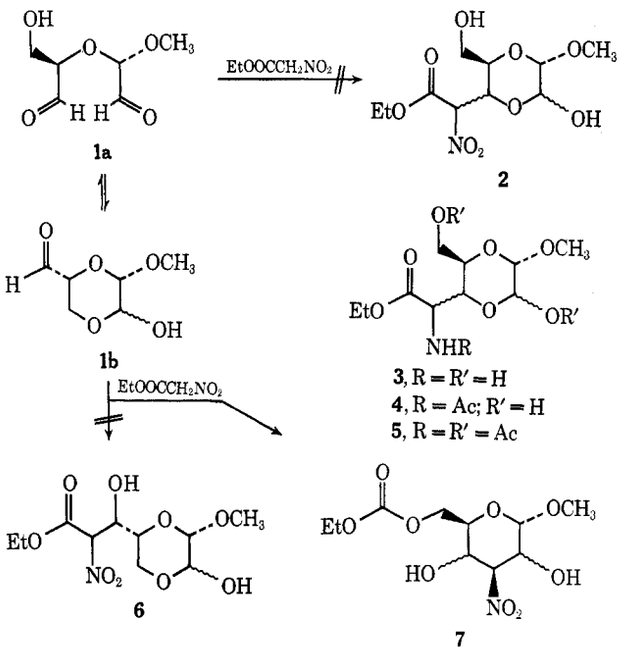
(5) D. Trimnell, W. M. Doane, C. R. Russel, and C. E. Rist, *Carbohyd. Res.*, **13**, 301 (1970).

(6) In naming **5**, we prefer this designation derived from *R*-glyceraldehyde rather than the previous system of E. L. Jackson and C. S. Hudson, *J. Amer. Chem. Soc.*, **59**, 994 (1937), according to which **5** would be a "D-3-methoxy-D-hydroxymethyldiglycolaldehyde."

(7) S. Zen, A. Yasuda, H. Hashimoto, and Y. Takeda, *Nippon Kagaku Zasshi*, **90**, 110 (1969); *Chem. Abstr.*, **70**, 97153 (1969).

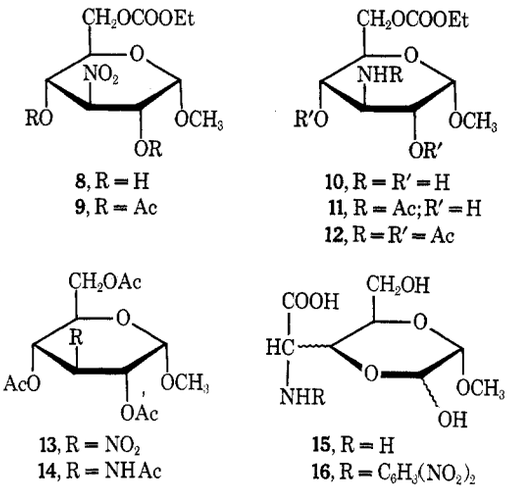
(8) H. Yanagisawa, M. Kinoshita, and S. Umezawa, *Bull. Chem. Soc. Jap.*, **42**, 1719 (1969).

stituent, as well as other dialdehydes[9] yield products of the normal dialdehyde–nitroalkane cyclization type on reaction with ethyl nitroacetate under essentially identical conditions. As has been pointed out,[10] these queries might be answered satisfactorily by invoking structure **6**, formed by addition of ethyl nitroacetate to the free aldehyde function in the internal hemiacetal **1b**. However, as shown by the results presented below, the products from this reaction have neither structure **2** nor **6**, but are tetrahydropyran derivatives of general structure **7**.



When dialdehyde **1a** ⇌ **1b** was treated with ethyl nitroacetate in aqueous ethanol in the presence of either sodium acetate or sodium carbonate (pH 8.6)[7] or, experimentally more convenient, 1 molar equiv of sodium hydroxide, a sirupy mixture was obtained on deionization which consisted (tlc) of two major components in a 5:2 ratio (nmr). This material was later shown to be the nitroglucoside **8** and its C-2-epimeric manno analog. Two minor products amounting to about 5% of the total mixture were not further characterized, but by analogy with the product distribution of the nitromethane cyclization of **1**[11] may be the galacto and the talo isomers of **8**. Elution of the product mixture from silica gel afforded **8** as a colorless sirup that was contaminated with only traces of the manno analog. A crystalline di-*O*-acetate was obtained on treatment of **8** with BF_3–acetic anhydride. Catalytic hydrogenation yielded the aminoglucoside **10** which on acetylation gave the triacetate **12**. Despite minor differences in melting points and rotations, the properties of **10** and **12** are sufficiently close to those of the alleged compounds **3** and **5** described by Zen, *et al.*,[7] to lead to the conclusion that the products obtained are the same substances and, hence, that structures **3**–**5** will have to be revised to **10**–**12**, respectively, based on the evidence to be presented.

Structural and configurational assignments for compounds **8**–**12** rest on chemical as well as on spectroscopic evidence. Firstly, hydrolysis of the 6-*O*-ethoxycarbonyl group in the nitroglucoside **8** with methanolic ammonia afforded methyl 3-deoxy-3-nitro-α-D-glucopyranoside,[12] characterized as its crystalline triacetate **13**. Similarly, the 6-*O*-ethoxycarbonyl aminoglucoside **12** on treatment with methanolic ammonia and subsequent acetylation gave a crystalline tetraacetate, shown to be methyl 3-acetamido-3-deoxy-2,4,6-tri-*O*-acetyl-α-D-glucopyranoside (**14**) by melting point, rotation,[11] and nmr data.[13,14] On the basis of these results, the structure of the supposed **15**, obtained on hydrolysis of the alleged **3** (revised, **10**) with barium hydroxide[7] and its 2,4-dinitrophenyl derivative **16**, must be revised to that of methyl 3-amino-3-deoxy-α-D-glucopyranoside and its 2,4-DNP derivative, despite discrepancies in the reported[7] analytical data.



Secondly, comparison of the mass spectral fragmentation patterns of methyl 3-deoxy-3-nitro-2,4,6-tri-*O*-acetyl-β-D-glucopyranoside[15] or its α anomer **13**, which are expectedly[16] identical, except for intensity differences, with those of the 6-ethoxycarbonyl nitroglucoside **9** showed only minor deviations of 30 mass units (C_2H_5O *vs.* CH_3) in the region of higher mass numbers, in which the C-acyl moiety is still present. Below *m/e* 200, the spectra of **9** and **13** (or its β anomer) become essentially identical, showing significant peaks at *m/e* 81, 99, and 141. These peaks can readily be attributed to ions stemming from a series, initiated by rupture of the C-1–C-2 and/or C-5–C-6 bonds followed by loss of the nitro, acetoxy, and C-6 acyloxy groups.[17] Since very similar relationships were revealed in the mass spectra of the aminoglucosides **12** and **14**, the alternative structures, *i.e.*, **2** and **5**, can be ruled out unequivocally.

Finally, the nmr data of the 6-*O*-ethoxycarbonyl glucosides **9** and **12**, when compared with those of their

(9) S. Yen, Y. Takeda, A. Yasuda, and S. Umezawa, *Bull. Chem. Soc. Jap.*, **40**, 431 (1967); S. Zen and A. Nishikai, *ibid.*, **42**, 1761 (1969).

(10) F. W. Lichtenthaler, *Fortschr. Chem. Forsch.*, **14**, 572 (1970).

(11) H. H. Baer, *J. Amer. Chem. Soc.*, **84**, 83 (1962).

(12) H. H. Baer, F. Kienzle, and T. Neilson, *Can. J. Chem.*, **43**, 1829 (1965).

(13) H. Agahigian, G. D. Vickers, M. H. von Saltza, J. Reid, A. I. Cohen, and H. Gauthier, *J. Org. Chem.*, **30**, 1085 (1965).

(14) The anomeric proton in **14** appears within the complex 4 H multiplet centered around τ 5.2, and not at τ 5.83, as previously reported.[13]

(15) H. H. Baer, F. Kienzle, and F. Rajabalee, *Can. J. Chem.*, **46**, 80 (1968).

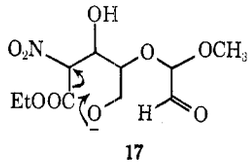
(16) K. Heyns, H. F. Grützmacher, H. Scharmann, and D. Müller, *Fortschr. Chem. Forsch.*, **5**, 448 (1966); N. K. Kochetkov and O. S. Chizhov, *Advan. Carbohyd. Chem.*, **21**, 39 (1966).

(17) For a detailed discussion of the various fragmentation routes of peracetylated 3-deoxy-3-nitrohexopyranosides *cf.* ref 2a and W. Fischer, Doctoral Dissertation, Technische Hochschule Darmstadt, April 1972.

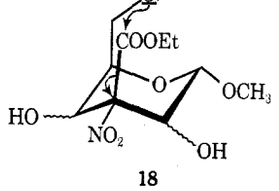
6-*O*-acetyl analog **13** and **14**, correspond convincingly to what one expects for an α-D-gluco configuration in these compounds. In the 100-MHz spectrum of the nitroglucoside **9** in $CDCl_3$, the multiplet splittings of the ring protons, despite partial overlapping, allowed a first-order interpretation, showing at τ 4.90 a small coupling (3.5 Hz) for the anomeric proton, while the 2,3-, 3,4-, and 4,5-coupling constants were in the range of 9.5–10.5 Hz, as expected for an axial orientation of H-5. These assignments are strongly supported by the nmr data of the tri-*O*-acetyl nitroglucoside **13**, in which the multiplet patterns for H-1–H-4 in the τ 4.4–5.2 range were superimposable on those of **9**. Similarly, the nmr features of **12** and **14**, in $CDCl_3$ and in DMSO-d_6, were identical, except for the signals caused by the ethyl group in **12** *vs.* the C-6-acetoxy resonance in **14**.

Several intermediates and/or mechanisms may be postulated to account for the conversion **1** → **7**. Of these, a direct ethoxycarbonyl transfer from the ethyl nitroacetate to the primary hydroxyl group in **1** prior to attack on a carbonyl function can be ruled out. If this occurred, a similar transfer to the ethanol or water present in the reaction medium would take place, giving, owing to the liberation of nitromethane, a mixture of products which would include methyl 3-deoxy-3-nitro-α-D-hexopyranosides. However, a direct comparison of the reaction mixture obtained on nitromethane cyclization of **1**[11] with the corresponding reaction mixture from **1** and ethyl nitroacetate showed (by tlc in several solvents) that none of the tlc spots were due to identical compounds.

Two mechanistic formulations appear to satisfy the experimental data presently available. In the first, which has good analogies with the readily occurring 4 → 6, O → O acyl migrations in hexopyranosides,[18] the C → O ethoxycarbonyl shift occurs in an intermediate of type **17**, formed from preferential attack of the nitroacetate carbanion at the unblocked aldehyde function (**1b** → **6**) with subsequent opening of the hemiacetal ring. The resulting 1-aldehydo-6-nitro derivative is then converted into **7** by cyclizing addition. In the alternative mechanism, a normal dialdehyde–nitroalkane cyclization to **18** takes place, followed by the C → O migration of the ethoxycarbonyl moiety.



17



18

There seems to be no way at present to decide which of these mechanisms is operating. However, the C → O ethoxycarbonyl shift may be circumvented by blocking the primary hydroxyl function in **1**, *e.g.*, by tritylation of the dialdehyde precursor. Since compounds of type **18** will then be accessible by detritylation of the products, an investigation of their behavior towards base will decide between the two mechanisms. These aspects are currently being studied.

(18) R. U. Lemieux, in P. de Mayo, Ed., "Molecular Rearrangements," Part 2, Interscience, New York, N. Y., 1964, p 763 ff, and literature cited therein.

Experimental Section[19]

Reaction of Ethyl Nitroacetate with 2-*O*-(*S*-Methoxyformyl)-methyl-(*R*)-glyceraldehyde.[6] **(1). Mixture of Methyl 3-Deoxy-6-*O*-ethoxycarbonyl-3-nitro-α-D-hexopyranosides (7).**—To a solution of dialdehyde **1** [obtained from 7.8 g (0.04 mol) of methyl α-D-glucopyranoside by periodate oxidation[20]] and 5.3 g (0.04 mol) of ethyl nitroacetate in 50 ml of ethanol was added 20 ml (1 molar equiv) of 2 *N* sodium hydroxide and the mixture was kept at ambient temperature for 1 hr. Deionization with a strongly acidic ion exchange resin (Merck I), filtration, and evaporation afforded a reddish sirup, which was dissolved in a little ethanol and purified by chromatography on silica gel with 5:1 benzene–2-propanone. After evaporation of the appropriate fractions a yellowish "sirup A" (6.3 g, 53%, based on methyl α-D-glucoside) was obtained. Sirup A was composed of two minor components of R_f 0.53 and 0.72 (tlc in 1:1 benzene–ethyl acetate), that amount to 5% of the mixture, and two major products, the gluco compound **8** and its manno analog of R_f 0.61 and 0.68, in a 5:1 ratio, as evidenced by the intensities of the two methoxy signals at τ 6.65 and 6.68, respectively, in DMSO-d_6. Elution of sirup A from silica gel with the same eluent gave two fractions; the first contained mainly the manno derivative,[21] whereas the second, on evaporation, afforded 4.8 g of a colorless oil (sirup B), being practically pure (tlc) gluco derivative **8**, contaminated with traces of manno compound. Sirup B, which was not amenable to crystallization from the usual solvents, was used for the further experiments: nmr (DMSO-d_6) τ 3.95 and 4.23 (d, 1, J = 7 Hz, C-2 and C-4 OH), 5.28 (d, 1, $J_{1,2}$ = 3.5 Hz, H-1), 5.37 (m, 2, H-2 and H-3), 5.80 (complex m, 6, H-4, H-5, C-6 CH_2, $EtCH_2$), 6.65 (s, 3, OCH_3), 8.77 (t, 3, J = 7 Hz, $EtCH_3$). Addition of trifluoroacetic acid eliminated the two OH doublets.

Anal. Calcd for $C_{10}H_{17}NO_9$: C, 40.68; H, 5.80; N, 4.74. Found: C, 40.45; H, 5.69; N, 4.60.

Methyl 3-Deoxy-2,4-di-*O*-acetyl-6-*O*-ethoxycarbonyl-3-nitro-α-D-glucopyranoside (9).—A solution of 1.65 g of sirup B in acetic anhydride (5 ml), containing 3 drops of boron trifluoride etherate, was kept for 2 hr at ambient temperature and subsequently taken to dryness *in vacuo* with repeated reevaporations from benzene. After treatment with activated carbon in benzene solution, the residue was triturated with ethanol, causing crystallization. Recrystallization from ethanol afforded 1.34 g (63%) of **9** as colorless crystals: mp 94–95°; $[\alpha]^{23}D$ +112° (*c* 1, $CHCl_3$); nmr (100 MHz in $CDCl_3$) τ 4.53 (t, 1, $J_{3,4} = J_{4,5}$ = 9.5 Hz, H-4), 4.69 (q, 1, $J_{1,2}$ = 3.5, $J_{2,3}$ = 10.5 Hz, H-2), 4.90 (d, 1, $J_{1,2}$ = 3.5 Hz, H-1), 4.99 (t, 1, H-3), 5.78 (m, 4, C-6 CH_2 and $EtCH_2$), 6.01 (m, 1, H-5), 6.56 (s, 3, OCH_3), 7.92 (s, 6, C-2 and C-4 OAc), 8.68 (t, 3, J = 7 Hz, $EtCH_3$); assignments were made by double resonance experiments.

Anal. Calcd for $C_{14}H_{21}NO_{11}$: C, 44.33; H, 5.58; N, 3.69. Found: C, 44.44; H, 5.44; N, 3.49.

Hydrolysis of the Ethoxycarbonyl Group in 9. Methyl 3-Deoxy-3-nitro-2,4,6-tri-*O*-acetyl-α-D-glucopyranoside (13).—Sirup B (220 mg) was kept in 10 ml of methanolic ammonia for 12 hr at room temperature and the solution was then taken to dryness followed by several reevaporations from methanol. After treatment with charcoal in water, a colorless sirup (80 mg, 53%) was obtained, which was allowed to stand for 2 hr in 3 ml of acetic anhydride containing a few drops of BF_3 etherate. Work-up as described for **9** afforded a sirup which was crystallized from water–ethanol to give 60 mg (25%) of **13** as needles: mp 83°; $[\alpha]^{23}D$ +122° (*c* 1, $CHCl_3$); nmr (100 MHz in $CDCl_3$) τ 4.50 (t, 1, $J_{3,4} = J_{4,5}$ = 9.5 Hz, H-4), 4.67 (q, 1, $J_{1,2}$ = 3.5, $J_{2,3}$ = 10.5 Hz, H-2), 4.90 (d, 1, H-1), 4.99 (t, 1, H-3), 5.78 (m, 2, C-6 CH_2), 6.02 (m, 1, H-5), 6.55 (s, 3, OCH_3), 7.88 (s, 3, C-6 OAc), 7.92 (s, 6, C-2 and C-4 OAc); the multiplet patterns in the

(19) Melting points were determined in a Bock Monoskop apparatus and are uncorrected. Nmr spectra were obtained on a Varian A-60 and Varian HA-100 spectrometer with tetramethylsilane as an internal standard; mass spectra were determined on an Atlas CH4 instrument.

(20) H. H. Baer and H. O. L. Fischer, *J. Amer. Chem. Soc.*, **82**, 3709 (1960).

(21) When subjected to BF_3-catalyzed acetylation, analogous to the conversion of **8** to **9**, a sirupy mixture was obtained containing approximately 30% of **9**. The manno configuration of the major part was clear from nmr data in $CDCl_3$, which showed, when compared to **9**, distinct differences in the splitting patterns of the ring protons: a quartet for H-2 at τ 4.46 with $J_{1,2}$ = 2.0 and $J_{2,3}$ = 3.5 Hz and, similarly, a quartet for H-3 at τ 5.02 with couplings of 10.5 and 3.5 Hz.

τ 4.4–5.2 region were superimposable with the corresponding ones of the 6-ethoxycarbonyl compound **9**.

Anal. Calcd for $C_{13}H_{19}NO_{10}$: C, 44.70; H, 5.48; N, 4.01. Found: C, 44.68; H, 5.39; N, 3.88.

Acid-catalyzed hydrolysis of the ethoxycarbonyl group in **9** could be effected, though rather retardedly, by refluxing sirup B with a strongly acidic ion exchange resin (Merck I) in methanol. As monitored by tlc (1:1 benzene–ethyl acetate) the reaction was still incomplete after 5 days, giving after work-up and acetylation as performed above, a tri-*O*-acetate in very low yield (3%), identical in all respects with **13**.

Methyl 3-Amino-3-deoxy-6-*O*-ethoxycarbonyl-α-D-glucopyranoside (10).—Sirup B (900 mg, 3.0 mmol) in 80 ml of ethanol was hydrogenated in the presence of 5 ml of Raney nickel T4 catalyst[22] for 3 hr at 100 atm. Removal of the catalyst followed by evaporation to dryness afforded a solid residue, which was chromatographically not homogeneous. After two recrystallizations from ethyl acetate, 200 mg (25%) of **10** was obtained as colorless crystals: mp 122–125° (reported[7] for alleged **3** mp 128.5–129.5°); nmr (D_2O) τ 5.24 (d, 1, $J_{1,2}$ = 3.5 Hz, H-1), 5.55 (m, 2, C-6 CH_2), 5.76 (q, 2, J = 7 Hz, $EtCH_2$), 6.15 (m, 1, H-5), 6.51 (q, 1, $J_{1,2}$ = 3.5, $J_{2,3}$ = 10 Hz, H-2), 6.59 (s, 3, OCH_3), 6.68 (t, 1, $J_{3,4} = J_{4,5}$ = 10 Hz, H-4), 7.05 (t, 1, H-3), 8.73 (t, 3, $EtCH_3$).

Anal. Calcd for $C_{10}H_{19}NO_7$: C, 45.28; H, 7.22; N, 5.28. Found: C, 45.12; H, 7.10; N, 5.35.

Methyl 3-Acetamido-3-deoxy-2,4-di-*O*-acetyl-6-*O*-ethoxycarbonyl-α-D-glucopyranoside (12).—To a prehydrogenated suspension of platinum (1 g) in 1:1 methanol–acetic anhydride (40 ml) was added 420 mg of nitrodi-*O*-acetate **9**, and the hydrogenation was continued in an autoclave at 100 atm of H_2 for 2 hr. Removal of the catalyst, which was thoroughly washed with methanol, and concentration of the combined filtrate and washings *in vacuo*, followed by repeated reevaporations from benzene, left a crystalline residue, which was filtered off (440 mg, quantitative). The crude product was recrystallized twice from ethanol to give 170 mg (40%) of **12** as colorless crystals: mp 179°; $[\alpha]^{23}D$ +102° (c 1, $CHCl_3$) [reported for alleged **5**[7] mp 177–178° from 2-propanol and $[\alpha]^{25}D$ +119° (c 1.1, $CHCl_3$)]; nmr (DMSO-d_6) τ 2.21 (d, 1, $J_{3,NH}$ = 9 Hz, NH), 5.1–5.4 (complex m, 3, H-1, H-2, and H-4), 5.7–6.2 (m, 6, H-3, H-5, C-6 CH_2 and $EtCH_2$), 6.66 (s, 3, OCH_3), 8.01 and 8.04 (s, 3, C-2 and C-4 OAc), 8.27 (s, 3, NHAc), 8.78 (t, 3, J = 7 Hz, $EtCH_3$).

Anal. Calcd for $C_{16}H_{25}NO_{10}$: C, 48.86; H, 6.41; N, 3.58. Found: C, 49.02; H, 6.55; N, 3.42.

Overnight treatment of the aminoglycoside **10** with pyridine–acetic anhydride at room temperature similarly afforded a triacetate, identical in all respects with **12**, as obtained above.

Methyl 3-Acetamido-3-deoxy-2,4,6-tri-*O*-acetyl-α-D-glucopyranoside (14).—A solution of 300 mg of triacetyl glucoside **12** in 20 ml of methanolic ammonia was kept at room temperature overnight, and subsequently taken to dryness with repeated reevaporations from methanol. The sirupy residue was dissolved in 2:1 pyridine–acetic anhydride (15 ml), and the resulting solution was kept overnight and then evaporated to dryness *in vacuo*. Several reevaporations from benzene and treatment with activated carbon in the same solvent left a residue on evaporation which crystallized on trituration with ethanol. Recrystallization from ethanol afforded 180 mg (65%) of **14**: mp 178–179°; $[\alpha]^{23}D$ +105° (c 1, $CHCl_3$) (mp 178–179°, $[\alpha]^{23}D$ +109°, reported previously[11]); nmr (DMSO-d_6) τ 2.23 (d, 1, $J_{3,NH}$ = 9 Hz, NH), 5.2 (m, 3 H-1, H-2, and H-4), 5.73 (broad m, 1, H-3), 5.96 (m, 3, H-5 and C-6 CH_2), 6.67 (s, 3, OCH_3), 8.00, 8.01, and 8.03 (s, 3, C-2, C-4, and C-6 OAc), 8.25 (s, 3, NHAc).

Anal. Calcd for $C_{15}H_{23}NO_9$: C, 49.86; H, 6.42; N, 3.88. Found: C, 49.97; H, 6.25; N, 3.61.

Registry No.—**8**, 34246-31-6; **8** manno derivative, 34280-29-0; **9**, 34246-26-9; **10**, 34246-27-0; **12**, 34280, 30-3; **13**, 34246-28-1; **14**, 2595-38-2.

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Studies Related to the Synthesis of (±)-Dihydro-β-santalol[1]

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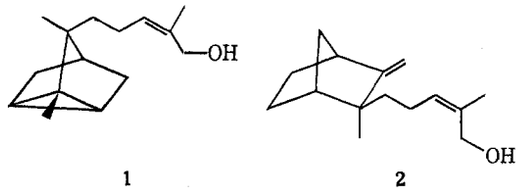
Several related schemes for the synthesis of the novel sesquiterpene dihydro-β-santalol (**3**), a material possessing the powerful, woody fragrance of East Indian sandalwood oil, are described. A preferred sequence utilizes boric acid esters as a means of protecting reactive hydroxyl groups during hydrobromination, alkylation, and Wittig reactions. A novel Meerwein–Ponndorf–Verley reduction discovered during these synthetic studies is also described.

East Indian sandalwood oil, an isolate of *Santalum album L.*, is a prized essential oil known for its powerful, sweet woody fragrance.[2] Although numerous minor components are important for the reproduction of the natural aroma of the oil, the two major components—α-santalol (**1**) and β-santalol (**2**)—are responsible for the basic sandalwood note. While syntheses of these two materials have been accomplished,[3] these schemes do not permit the accumulation of large amounts of material owing to the complexity of the natural sesquiterpene structures. The greater synthetic accessibility of compounds in the β series and the challenge to construct a simpler molecule with a powerful sandalwood note prompted us to synthesize dihydro-β-santalol (**3**).



1 **2**

Corey has shown[4] that either of the epimeric methylnorcamphors **4** or **5** undergoes stereoselective alkylation from the exo face to produce 3-*exo*-alkyl-3-*endo*-methylnorcamphors. Using this information, our synthetic scheme was to preconstruct a side chain—such as **6**—which on condensation with ketone **4** or **5** would be expected to yield stereoselectively a dihydro-β-santalol

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