Anal. Calcd. for $C_{29}H_{40}N_2O_3$: C, 74.96; H, 8.68; N, 6.03. Found: C, 74.91; H, 8.35; N, 6.15.

1,2,3,9,10,10aβ-Hexahydro-7-methoxy-2α-phenanthrenecarboxylic Acid Methyl Ester (IV).—A suspension of the acylurea III (465 mg.) was stirred in 10 ml. of methanol, and 10 ml. of 0.1 *N* sodium methoxide in methanol was added over 15 min. Stirring was continued for 16 hr. at room temperature. Ice–water (10 ml.) was then added, and the cold solution was neutralized carefully with 2 *N* hydrochloric acid. Most of the methanol was removed *in vacuo*, and the solution was filtered from the dicyclohexylurea.[8] The filtrate was extracted with hexane. The extract was dried with sodium sulfate and evaporated *in vacuo* to yield 272 mg. of the methyl ester IV, m.p. 71–72°. The compound was identical in every respect with the previously described methyl ester.[1]

N-Cyclohexyl-1,2,3,9,10,10aβ-hexahydro-7-methoxy-2α-phenanthrylcarboxamide (VI), Cyclohexylcarbamic Acid Isopropyl Ester (VIIIa), and Cyclohexylcarbamic Acid *t*-Butyl Ester (VIIIb).—The acylurea III (4.65 g.) was suspended in 100 ml. of anhydrous isopropyl alcohol or *t*-butyl alcohol. A 0.1 *N* solution (100 ml.) of the sodium alkoxide in the corresponding alcohol was added, and the mixture was stirred at room temperature for 16 hr. with the exclusion of moisture. It was then neutralized with 2 *N* hydrochloric acid and evaporated to dryness *in vacuo*. The residue was broken up under hexane, and the hexane-insoluble amide VI was filtered. Recrystallization from ethanol gave analytically pure VI: m.p. 221–222°; ultraviolet absorption, λ_{max}^{EtOH} 264 mμ (ε 20,600), 298 (3200); infrared absorption, ν_{max}^{KBr} 3300 (NH), 1635 cm.$^{-1}$ (carbonyl).

Anal. Calcd. for $C_{22}H_{29}NO_2$: C, 77.84; H, 8.61; N, 4.13. Found: C, 78.12; H, 8.76; N, 4.25.

To obtain the urethans (VIIIa or b), the filtrate of the amide VI was evaporated *in vacuo*, and the solid residue was recrystallized from an appropriate solvent. Recrystallization from petroleum ether (b.p. 30–60°) gave analytically pure cyclohexylcarbamic acid isopropyl ester (VIIIa): m.p. 66.5–67.0°; infrared absorption, $\nu_{max}^{CHCl_3}$ 3450 (NH), 1706 (carbonyl), 1515 cm.$^{-1}$ (amide II).

Anal. Calcd. for $C_{10}H_{19}NO_2$: C, 64.83; H, 10.34; N, 7.56. Found: C, 64.96; H, 10.11; N, 7.65.

Recrystallization from hexane gave analytically pure cyclohexylcarbamic acid *t*-butyl ester (VIIIb): m.p. 79–80°; infrared absorption, $\nu_{max}^{CHCl_3}$ 3450 (NH), 1705 (carbonyl), 1510 cm.$^{-1}$ (amide II).

Anal. Calcd. for $C_{11}H_{21}NO_2$: C, 66.29; H, 10.62; N, 7.03. Found: C, 66.20; H, 10.81; N, 7.00.

With sodium isopropoxide in isopropyl alchol, 3.4 g. of amide VI and 1.56 g. of urethan VIIIa (84.5%) were obtained. With sodium *t*-butoxide in *t*-butyl alcohol, 3.2 g. of amide VI and 1.6 g. of urethan VIIIb (80.3%) were obtained.

Cyclohexylcarbamic Acid Isopropyl Ester (VIIIa) and Cyclohexylcarbamic Acid *t*-Butyl Ester (VIIIb) from Cyclohexyl Isocyanate (VII).—The corresponding alcohol (10 ml.) was added to 12.5 g. of the isocyanate VII[9] and the reaction mixture was stirred at room temperature for 16 hr. Excess alcohol was evaporated *in vacuo*, and the dry residue was recrystallized from an appropriate solvent.

In the experiment with isopropyl alcohol, recrystallization from petroleum ether (b.p. 30–60°) gave 14.4 g. (78%) of the pure cyclohexylcarbamic acid isopropyl ester (VIIIa), which was identical in every respect with the compound described above.

The crude cyclohexylcarbamic acid *t*-butyl ester (VIIIb) was recrystallized from hexane to give 15.9 g. (80%) of the pure urethan (VIIIb), which was identical in every respect with the material obtained from the acylurea III with sodium *t*-butoxide in *t*-butyl alcohol.

Acknowledgment.—We wish to express our thanks to Mr. C. Parios for his technical assistance in this work. We are also indebted to Mr. S. Traiman for the infrared data, to Dr. V. Toome for the ultraviolet spectroscopic data, and to Dr. A. Steyermark for the microanalyses.

(9) Cyclohexyl isocyanate was obtained from K & K Laboratories, Inc., Plainview, N. Y.

3′-Deoxynucleosides. III.[1] 3′-Deoxyguanosine

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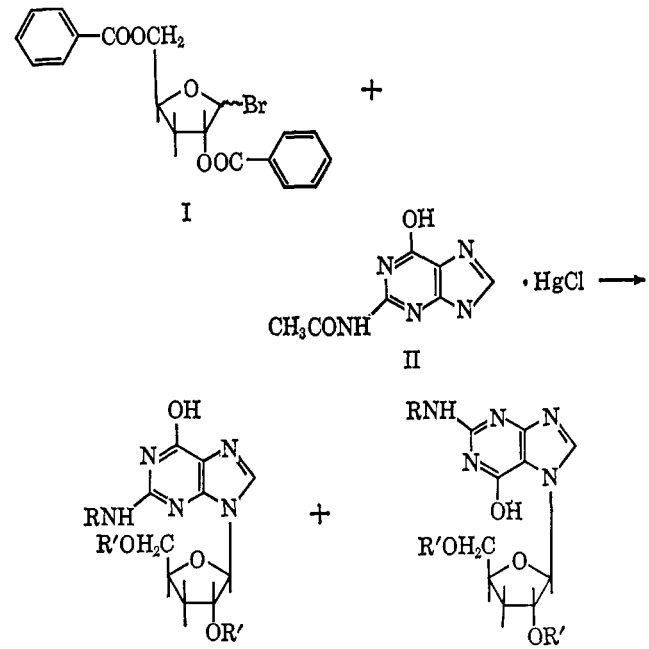
Received March 16, 1965

In view of the biological activity[2] of 3′-deoxyadenosine (cordycepin) it seemed desirable to synthesize the 3-deoxyriboside of guanine, the other major purine component of nucleic acids. Although numerous guanine glycosides have been synthesized[3] by transformation of the purine moiety of other nucleosides, only one has been prepared from guanine. In this instance, a condensation of acetobromoglucose with chloromercuri-2-acetamidohypoxanthine (II) gave[4] not only 9-(β-D-glucopyranosyl)guanine but also the isomeric 7-(β-D-glucopyranosyl)guanine. We have synthesized 3′-deoxyguanine by a procedure in which 2,5-di-O-benzoyl-3-deoxy-D-ribofuranosyl bromide (I) was condensed with the chloromercuripurine II. Since a ribofuranoside and a glucopyranoside have both been prepared from II, it would appear that this procedure has general utility for the synthesis of guanine nucleosides.

When 2,5-di-O-benzoyl-3-deoxy-D-ribofuranosyl bromide (I)[1] was coupled with chloromercuri-2-acetamido-



III, R=CH_3CO; R′=C_6H_5CO IV, R=CH_3CO; R′=C_6H_5CO

V, R=H; R′=H VI, R=H; R′=H

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(3) See J. A. Montgomery and H. J. Thomas, *Advan. Carbohydrate Chem.*, **17**, 301 (1962).

(4) Z. A. Shabarova, Z. P. Polyakova, and M. A. Prokofev, *Zh. Obshch. Khim.*, **29**, 215 (1959).

hypoxanthine (II), both the 9- and 7-isomers (III and IV) of (2,5-di-O-benzoyl-3-deoxy-β-D-ribofuranosyl)-2-acetamidohypoxanthine were formed in about equal amounts. They were separated readily by chromatography on alumina and were deactylated in methanolic sodium methoxide to the corresponding guanine 3′-deoxynucleosides V and VI.

The assignment of the position of attachment of the sugar moiety in the 7- and 9-(glucopyranosyl)guanines was made[4] primarily on the basis of a comparison of their ultraviolet absorption with that of authentic 7- and 9-methylated guanines.[5] Since then, absorption spectra of guanines substituted in other than the 7- and 9-positions have become available[6] and because they differ with the spectra for the 7- and 9-substituted products, they substantiate the earlier structural conclusions. Similarly, we have assigned the position of linkage of the 3-deoxyribofuranosyl moiety in V and VI as 9 and 7 on the basis of ultraviolet spectral comparisons.

These new 3-deoxyribofuranosylguanines have been tested[7] in several biological systems in order to compare their activities with those of other purine 3′-deoxynucleosides.

Experimental[8]

9-(2,5-Di-O-benzoyl-3-deoxy-β-D-ribofuranosyl)-2-acetamidohypoxanthine (III) and 7-(2,5-Di-O-benzoyl-3-deoxy-β-D-ribofuranosyl)-2-acetamidohypoxanthine (IV).—About 25 ml. of xylene was distilled from a suspension of 5.95 g. (14 mmoles) of chloromercuri-2-acetamidohypoxanthine (II)[4] in 175 ml. of xylene in order to remove last traces of water. The suspension was cooled to 25° and 2,5-di-O-benzoyl-3-deoxy-D-ribofuranosyl bromide [from 5 g. (12.3 mmoles) of methyl 2,5-di-O-benzoyl-3-deoxy-β-D-ribofuranoside][1] in 25 ml. of dry xylene was added. The mixture was stirred and heated. At about 50 to 100°, the solid changed from a granular to flocculent form. After being refluxed for 1 hr., the hot mixture was filtered which removed 5.5 g. of solid. Leaching the solid with three 50-ml. portions of boiling chloroform removed 1.9 g. of soluble product and left 3.6 g. of starting chloromercuri derivative and inorganic salts.

The original filtrate was diluted with 2 vol. of petroleum ether (b.p. 30–60°) and the solid which separated was dissolved in the chloroform solution obtained above. The chloroform solution (plus an additional 100 ml.) was washed with two 75-ml. portions of 30% potassium iodide and one 75-ml. portion of water. The dried chloroform layer was concentrated and 3.5 g. of crude coupling product was obtained as a glass. T.l.c. on alumina in acetone–ethyl acetate (3:1) showed zones (made visible with iodine vapor) at R_f 0.0, 0.4, and 0.7.

The crude product was chromatographed on 50 g. of acid-washed alumina. Elution with 120 ml. of ethyl acetate removed 600 mg. of an impurity (R_f 0.7) derived from the bromo sugar. Further elution with about 700 ml. of acetone removed 1.17 g. of another component (R_f 0.4). This material was dissolved in 100 ml. of chloroform and washed with water. Concentration of the chloroform layer gave 1.05 g. (16.5%) of 7-(2,5-di-O-benzoyl-3-deoxy-β-D-ribofuranosyl)-2-acetamidohypoxanthine as an amorphous powder: $[\alpha]_D$ −19.3°; $[\alpha]_{578}$ −21° (*c* 1.0, $CHCl_3$); λ_{max}^{EtOH}, mμ (ε × 10^{-3}), 232 (27.9), 254 (16.5), 260 (15.0), 276 (12.1), 282 (11.9).

Anal. Calcd. for $C_{26}H_{23}N_5O_7$: C, 60.34; H, 4.48; N, 13.53. Found: C, 60.80; H, 4.48; N, 13.49.

Column elution was continued with methanol (750 ml.) which removed 900 mg. of product of R_f 0.0 on alumina t.l.c. in the acetone–ethyl acetate (3:1) system. This material was dissolved in 200 ml. of chloroform and washed with two 20-ml. portions of water. Concentration of the filtered chloroform solution under reduced pressure gave 740 mg. (12%) of 9-(2,5-di-O-benzoyl-3-deoxy-β-D-ribofuranosyl)-2-acetamidohypoxanthine as an amorphous solid: $[\alpha]_D$ −72°; $[\alpha]_{578}$ −76° (*c* 1.0, $CHCl_3$); λ_{max}^{EtOH}, mμ (ε × 10^{-3}), 225 (38.1), 267 (14.6), 280 (infl.) (12.1).

Anal. Found: C, 61.08; H, 4.75; N, 13.47.

9-(3-Deoxy-β-D-ribofuranosyl)guanine (3′-Deoxyguanosine, V).—A suspension of 800 mg. (1.5 mmoles) of 2-acetamido-9-(2,5-di-O-benzoyl-3-deoxy-β-D-ribofuranosyl)hypoxanthine (III) in 8 ml. of dry methanol was treated with a solution prepared from 105 mg. (4.5 g.-atoms) of sodium and 8 ml. of dry methanol, and the mixture was refluxed for 2 hr. After 15 min. of refluxing, no further change in the ultraviolet absorption spectrum could be observed. The mixture was concentrated to dryness. The residue was dissolved in 35 ml. of water and the pH was adjusted to 7 by the addition of acetic acid. The clear solution was washed with three 8-ml. portions of chloroform, and the aqueous layer was concentrated to 10 ml. After being cooled for several hours, the precipitated product (260 mg.) was removed and washed with two 2.5-ml. portions of cold water. Recrystallization from 11 ml. of water gave 203 mg. of 9-(3-deoxy-β-D-ribofuranosyl)guanine. A second recrystallization gave 180 mg. (46%) of product, m.p. >300°, which was dried at 80° and reduced pressure for analysis: $[\alpha]_D$ −41.2°; $[\alpha]_{578}$ −44° (*c* 0.5, H_2O); $\lambda_{max}^{H_2O}$, mμ (ε × 10^{-3}), pH 1—255 (11.3), 275 (infl.) (7.6), pH 4—252 (11.9), 270 (infl.) (8.6), pH 6—252 (12.1), 272 (infl.) (8.8), pH 7—252 (11.8), 270 (infl.) (8.6), pH 11—253 (11.3), 270 (infl.) (8.95), pH 13—267 (9.9), 260 (infl.) (9.7).

Anal. Calcd. for $C_{10}H_{13}N_5O_4$: C, 44.94; H, 4.90; N, 26.21. Found: C, 44.90; H, 4.97; N, 26.24.

7-(3-Deoxy-β-D-ribofuranosyl)guanine (VI).—A suspension of 900 mg. (1.74 mmoles) of 2-acetamido-7-(2,5-di-O-benzoyl-3-deoxy-β-D-ribofuranosyl)guanine (IV) in 8 ml. of dry methanol was treated with a solution prepared from 132 mg. (5.7 g.-atoms) of sodium and 8 ml. of dry methanol, and the mixture was refluxed for 3.5 hr. Periodic examination of the ultraviolet absorption spectrum indicated that the reaction was complete after 2.5 hr. The mixture was concentrated and the residue was dissolved in 40 ml. of water. The solution was washed with 15 ml. of chloroform and the pH of the aqueous phase was adjusted to 7 with acetic acid. The precipitated product (356 mg.) was filtered and washed with 5 ml. of water, 10 ml. of alcohol–ether (1:9), two 10-ml. portions of boiling chloroform, and 10 ml. of ether. Two recrystallizations from water gave 247 mg. (53%) of 7-(3-deoxy-β-D-ribofuranosyl)guanine: m.p. >300°; $[\alpha]_D$ −10°; $[\alpha]_{578}$ −10° (*c* 0.25, 1 *N* NaOH); $\lambda_{max}^{H_2O}$, mμ (ε × 10^{-3}), pH 1—249 (8.6), 270 (infl.) (5.0), pH 4—240 (infl.) (4.6), 284 (5.1), pH 6—217 (17.7), 240 (infl.) (5.1), 285 (6.0), pH 7—217 (19.1), 242 (infl.) (5.6), 286 (6.3), pH 11—215 (19.6), 237 (infl.) (6.0), 285 (6.3), pH 13—238 (infl.) (7.0), 282 (5.6).

Anal. Calcd. for $C_{10}H_{13}N_5O_4$: C, 44.94, H, 4.90; N, 26.21. Found: C, 45.00; H, 4.85; N, 26.47.

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(8) Microanalyses were performed by Mr. R. N. Boos and his associates, and the ultraviolet spectral measurements were done by Mr. E. A. MacMullin and his associates. Melting points were determined on a micro hot stage and are corrected.

Quaternary Ammonium Borodisalicylates and Borodihydroxynaphthoates

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Received April 6, 1965

Although syntheses of borodisalicylic acid have been reported,[1] both the existence and properties of this substance are still subject to question. The metal and amine salts of this acid, however, are well known

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