sublimed at 90 °C (10^{-2} Torr) to give 0.890 g of unreacted **1** (52% recovery). A red solid remained which was dissolved in methylene chloride. Alumina (1 g) was added, the solvent was removed in vacuo and the material was added to a dry alumina column (2 × 20 cm). Elution with benzene gave a red band. The solvent was removed and the residue was crystallized from chloroform to give 0.075 g (5%) of tetrakis(pentafluorophenyl)cyclopentadienone (**4**), which was identified by comparison to a known sample: mp 243–244 °C (lit.[2] 231–231.5 °C); M^+ 744 (mass spectrometry) (calcd: 744).

Method C. Bis(pentafluorophenyl)acetylene (1.00 g, 2.79 mmol) and bis(tetracarbonylcobalt)mercury (0.100 g, 0.184 mmol) were refluxed in 25 mL of dioxane for 4.5 h under nitrogen with magnetic stirring. The reaction mixture was cooled and filtered in air, and the residue was washed with methylene chloride to give small amounts of metallic mercury. The solvent was removed from the filtrate and the residue sublimed at 90 °C (10^{-3} Torr) to give 0.834 g (83% recovery) of unreacted **1**. Further sublimation of the residue at 200–205 °C (10^{-3} Torr) gave 0.012 g of **3** (1.2%, 7.2% based on unrecovered **1**).

Acknowledgments. Acknowledgment is made to the National Science Foundation and to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for financial support of this work. The authors are also grateful to Dr. H. Gilman and Dr. W. Hübel for helpful suggestions concerning the syntheses of **1** and **3**, respectively. The assistance of Mr. David Levine in certain aspects of the experimental work is also appreciated. M.D.R. is grateful to the Alexander Von Humboldt-Stiftung, Bonn/Bad Godesburg, West Germany, for a fellowship.

Registry No.—**1**, 13551-43-2; **2**, 13509-88-1; **3**, 35525-35-0; **4**, 15070-92-5; bromopentafluorobenzene, 344-04-7; tetrabromethylene, 79-28-7; pentafluorophenylcopper, 18206-43-4; phenylacetylene, 536-74-3; phenyliodoacetylene, 932-88-7; bis(tetracarbonylcobalt)-mercury, 13964-88-0.

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(20) A shorter reflux period may be used, although **1** is obtained in somewhat lower yield.
(21) The preparations of pentafluorophenylcopper and phenyliodoacetylene were timed to coincide as closely as possible in order to minimize the formation of undesirable coupling products.

Preparation of 9-(5-Deoxy-α-D-arabinofuranosyl)adenine from D-Ribose[1]

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Aldofuranose derivatives that have three contiguous hydroxyl groups, with the hydroxyls at C-2 and C-3 in a cis relationship, will undergo epimerization at C-2 when acetolyzed in a mixture containing acetic acid, acetic anhydride, and sulfuric acid. This reaction was originally discovered by Jerkeman[2] and later studied in greater detail by Sowa[3] and others.[4] In recent years, it has been developed into a useful preparative reaction with hexofuranose derivatives, and optimal conditions have been found to consist of 10:1 acetic acid–acetic anhydride and 3–5% concentrated sulfuric acid.[5] This reaction has been useful in the development of new routes to rare sugars and in the synthesis of novel hexofuranosyl nucleosides.[6] Usually, no significant amounts of the reactant sugars or of their nucleosides have been found upon isolation of products. In more recent, unpublished experiments, it was found that certain 6-deoxyhexofuranosyl derivatives afforded only about a 50% yield of the C-2 epimerized products upon acetolysis. There was an interesting structural property of these latter derivatives that was striking. All of the original group of hexofuranose derivatives had hydroxyl groups at C-2 and C-3 which were on the same side of the furanose ring as the C-4 tail end of the sugar. In the cases involving incomplete epimerization the hydroxyl groups were on the opposite side of the ring from the C-4 group. It was of some interest, therefore, to compare results with a pentose having the same structural relationship. Because of the continuing interest in nucleosides of potential biological value, the preparation of 9-(5-deoxy-α-D-arabinofuranosyl)adenine (**5**) was undertaken starting from D-ribose.

D-Ribose was converted to methyl 2,3-*O*-isopropylidene-5-*O*-*p*-toluenesulfonyl-β-D-ribofuranoside (**1**) in two steps (Scheme I).[7] The terminal carbon atom was reduced with sodium borohydride in dimethyl sulfoxide[8] to afford methyl 5-deoxy-2,3-*O*-isopropylidene-β-D-ribofuranoside (**2**). Acetolysis of **2** gave a syrup (**3**) which was coupled with 6-benzamidochloromercuripurine in refluxing 1,2-dichloroethane in the presence of titanium tetrachloride.[9] The blocked nucleoside (**4**) was treated with sodium methoxide in methanol and **5** was obtained after purification by chromatography on an anion-exchange column.[10]

The elemental analysis of **5** indicated a nucleoside with the correct empirical formula. The UV spectrum supported a sugar linked to adenine at N-9. The melting point and optical rotation data are clearly different from either 9-(5-deoxy-β-D-ribofuranosyl)adenine[11] or 9-(5-deoxy-β-D-xylofuranosyl)adenine.[12] The slow rate of periodate consumption (0.87 molar equiv in 48 h) provided proof that the hydroxyl groups at C-2 and C-3 were arranged trans to each other, and this again eliminated the ribo configuration and, in addition, the lyxo configuration for the nucleoside. The data suggested that the product was **5**, which was what was expected from recent experience with this reaction pathway.[5,6]

The configuration of **5** at the anomeric carbon could not be deduced from the NMR spectrum because a trans arrangement for the H-1′, H-2′ protons can only be unequivocally concluded if $J_{1',2'} < 1$ Hz.[13] In this case, **5** had $J_{1',2'} = 4$ Hz. A comparison of the optical rotation of **5** with that of other pentofuranosyladenine nucleosides supported an α-D configuration. A proof of configuration was obtained by periodate

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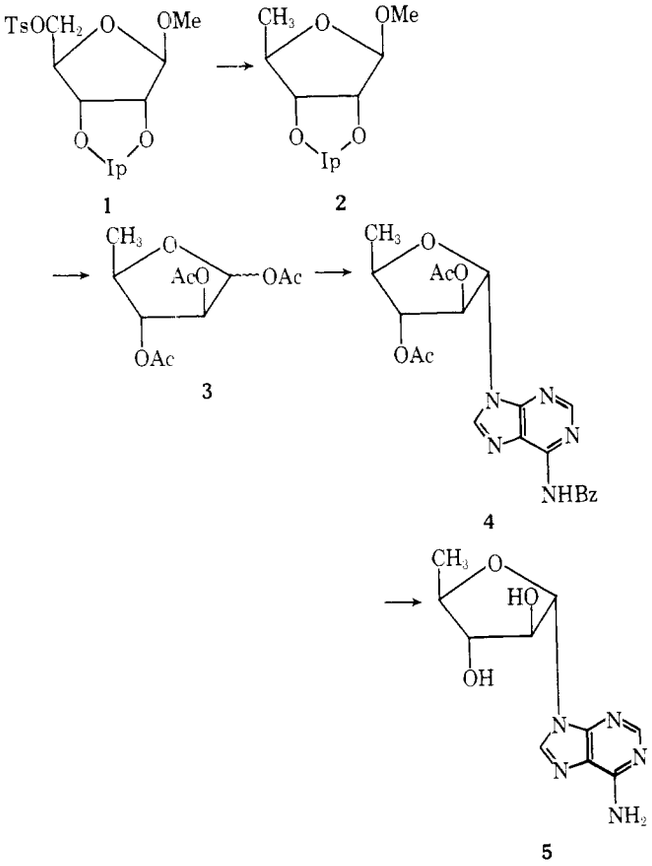
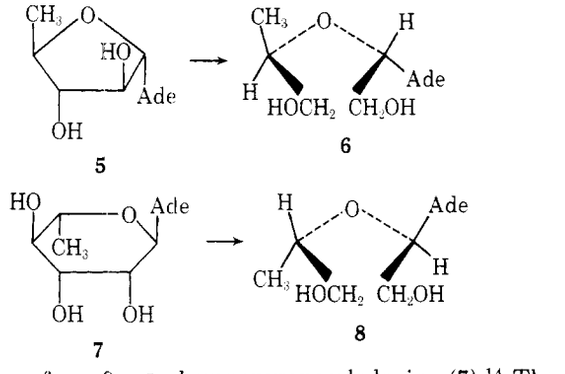
Scheme I



oxidation, followed by sodium borohydride reduction of the aldehyde groups to give alcohol **6**. This nucleoside alcohol is the enantiomer of the known dialcohol **8**, the optical rotation of which was previously obtained in a similar experiment.[5] Compound **8** has also been prepared as a pure, crystalline



substance from 9-α-L-rhamnopyranosyladenine (**7**).[14] The latter had to be used as the reference because the D form has never been prepared. The optical rotations of **6** and **8** were nearly equal in value, but opposite in sign.

Experimental Section[15]

Methyl 5-Deoxy-2,3-*O*-isopropylidene-β-D-ribofuranoside (2). To a solution containing 5.45 g (15.2 mmol) of methyl 2,3-*O*-isopropylidene-5-*O*-*p*-toluenesulfonyl-β-D-ribofuranoside[7] (**1**) in 40 mL of dimethyl sulfoxide was added 2.3 g of sodium borohydride and the mixture was stirred at 80–85 °C for 22 h. After cooling the flask to room temperature, the mixture was poured into 125 mL of 1% aqueous acetic acid solution and stirred for 15 min, and the product was extracted with chloroform (5 × 25 mL). The chloroform solution was washed with water (4 × 250 mL) and dried (anhydrous magnesium sulfate). Evaporation of the chloroform gave a clear, colorless liquid which gave 2.01 g (70% yield) of **2** upon distillation: bp 29–30 °C (0.05 mmHg); $[\alpha]^{26}_D$ −116° (*c* 2.57, ethanol) [lit.[16] $[\alpha]^{23}_D$ −109° (*c* 2, ethanol)].

9-(5-Deoxy-α-D-arabinofuranosyl)adenine (5). The sugar derivative **2** (1.95 g, 10.4 mmol) was dissolved in a mixture containing 6 mL of acetic anhydride and 60 mL of acetic acid and chilled in an ice bath while 3.3 mL of concentrated sulfuric acid was slowly added dropwise. The mixture was kept at room temperature for 69 h, poured into 125 mL of ice, and stirred until the ice had melted. The mixture was extracted with chloroform (4 × 30 mL), and the chloroform solution was washed with water (2 × 200 mL), saturated sodium bicarbonate (200 mL), and water (200 mL), and dried (anhydrous magnesium sulfate). Evaporation and coevaporation with benzene several times to remove traces of acetic acid gave a syrup, 1.92 g (71% yield), of crude product **3**.

The entire syrup was dissolved in 255 mL of 1,2-dichloroethane, 4.2 g of 6-benzamidochloromercuripurine and 4.2 g of Celite-545 were added, and 40 mL of the solvent was distilled to ensure the absence of moisture. A solution containing 1.1 mL of titanium tetrachloride in 40 mL of fresh, dry 1,2-dichloroethane was added and the mixture was stirred under reflux for 21 h, protected from moisture. The flask was allowed to cool to room temperature, treated with 150 mL of saturated sodium bicarbonate, and stirred for 1.5 h. The insoluble material was removed by filtration through a pad of Celite and the filter cake was washed with 100 mL of hot solvent. The organic layer was separated and the solvent was removed by evaporation. The remaining foam was dissolved in 75 mL of chloroform, washed with 30% aqueous potassium iodide (2 × 100 mL) and water (150 mL), and dried (anhydrous magnesium sulfate). Evaporation of the solvent afforded a pale-yellow foam, 2.37 g. The foam was dissolved in 60 mL of methanol and treated with 5 mL of 1 N sodium methoxide in methanol. The solution was heated under reflux for 1 h, cooled to room temperature, and adjusted to neutral pH with Amberlite CG-120 (H^+) resin. The resin was removed by filtration and washed thoroughly with methanol. The methanol was evaporated, and the residue was dissolved in a minimum amount of water and applied to a column (28 cm × 2.3 cm) of Bio-Rad AG 1-X2 (OH^-, 200–400 mesh) ion-exchange resin. Elution was performed with 7:3 water–methanol and 11-mL fractions were collected. The only major peak appeared in tubes 13–36. These were pooled, the solvents were evaporated, and the residue was dried by coevaporation with absolute ethanol several times, leaving a white foam (850 mg). Crystallization was effected by dissolution in methanol, addition of ethyl acetate, and concentration by boiling on a steam bath until the temperature changed from 64 to 74 °C. The solution was kept at room temperature and crystallization proceeded to afford 516 mg, mp 187–189 °C. Two additional crops of crystals were obtained by concentrating the mother liquors, which brought the yield to 758 mg (40.8% from **3**). An analytical sample was obtained by recrystallization from a large volume of ethyl acetate in an open flask. Clusters of crystals formed on the walls: 417 mg; mp 193–195 °C with softening starting at 185 °C; $[\alpha]^{27}_D$ +78.1° (*c* 0.741, 1:1 dimethylformamide–water); UV max (H_2O) 259 nm (ε 14,800); NMR (Me_2SO-d_6) δ 8.15, 8.02 (both s, 1 proton each, H-8, H-2), 7.12 (br s, 2, NH_2), 5.77 (d, $J_{1',2'}$ = 4 Hz, H-1'), 1.20 (d, 3, C-5' CH_3).

Anal. Calcd for $C_{10}H_{13}N_5O_3$: C, 47.80; H, 5.21; N, 27.88. Found: C, 47.75; H, 5.18; N, 27.87.

Periodate Uptake. The consumption of periodate was followed by the spectrophotometric procedure of Rammler and Rabinowitz.[17] It required 48 h for **5** to consume 0.87 molar equiv of periodate.

Polarimetric Study. Nucleoside **5** (12.10 mg) was dissolved in 0.75 mL of hot water, cooled to room temperature, 0.5 mL of 0.25 M sodium periodate added, and the sample placed in the dark. Three days later, 0.1 mL of 0.503 M formic acid was added and the solution was then treated with 60 mg of sodium borohydride. After 1 h, 0.4 mL of 20% aqueous acetic acid was added to destroy excess hydride. Effervescence stopped after 2 h, the solution was adjusted to 2 mL, and the optical rotation recorded, $[\alpha]^{26}_D$ −71°. Treatment of **7** in the same manner gave $[\alpha]_D$ +74°.

Registry No.—**1**, 4137-56-8; **2**, 23202-81-5; **3**, 63903-44-6; **4**, 63865-81-6; **5**, 63865-82-7; 6-benzamidochloromercuripurine, 17187-65-4.

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Steroid *B*-Ring Lactones: a Reinvestigation

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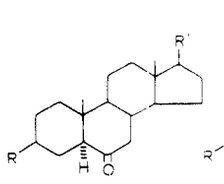
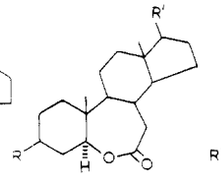
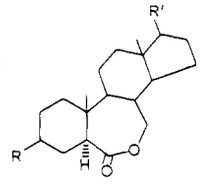
In the Baeyer–Villiger oxidation, the migratory aptitude of alkyl groups decreases in the order tertiary, secondary, primary, and methyl. This tendency is a function of the ability of the migrating group to support a positive charge in the transition state.[1] Accordingly, Fonken and Miles[2] showed that the peracid oxidation of 6-keto steroids is a stereospecific process leading exclusively to 6-oxa steroids by preferential migration of the more substituted C-5. Subsequently, we also reported similar observations.[3] Lately we noted that 6-keto-5α-β-sitostanyl acetate (**1**) on perbenzoic acid (1 molar equiv) oxidation gave the anticipated 6-oxa lactone **2** as well as its 7-oxa isomer **3** arising through migration of the less substituted C-7,[4,5] structures being established spectroscopically beyond doubt. This apparently unusual observation forced us to reexamine the reactions which had led to previous conclusions.[2,3]



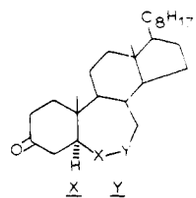
	R	R′
1	OAc	$C_{10}H_{21}$
4	OAc	C_8H_{17}
9	OH	C_8H_{17}
16	H	C_8H_{17}
19	Cl	C_8H_{17}
22	Br	C_8H_{17}



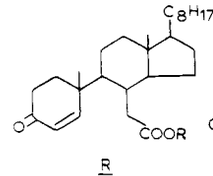
	R	R′
2	OAc	$C_{10}H_{21}$
5	OAc	C_8H_{17}
7	OH	C_8H_{17}
17	H	C_8H_{17}
20	Cl	C_8H_{17}
23	Br	C_8H_{17}



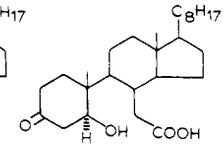
	R	R′
3	OAc	$C_{10}H_{21}$
6	OAc	C_8H_{17}
8	OH	C_8H_{17}
18	H	C_8H_{17}
21	Cl	C_8H_{17}
24	Br	C_8H_{17}



	X	Y
10	O	CO
11	CO	O



	R
12	H
13	CH_3



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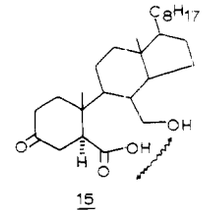

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Similarly, 5α-cholestan-6-one (**16**) provided the isomeric lactones **17** and **18**, and its 3β-halogen analogues **19** and **22** furnished **20, 21,** and **23, 24,** respectively. On sodium–pentyl alcohol reduction **20** and **23** afforded **17,** while **21** and **24** were transformed into **18.**

An interesting feature of the NMR spectra of both 6- and 7-oxa lactones was the appearance of one of the C-7a protons as a broadened singlet and the other as a doublet with J = 3–5 Hz. Examination of the Dreiding models of the isomeric lactones revealed that the dihedral angle between the planes of C-8–βH (axial) and C-7a–βH (pseudoequatorial) is almost 90°, which may account for its (C-7a–βH) appearance as a broadened singlet, as splitting will be almost negligible. On the other hand, C-8–βH splits C-7a–αH (pseudoaxial) into a doublet.

The point which emerges from this restudy is that a secondary carbon (C-7) competes quite effectively with a tertiary one (C-5) for migration to an electron-deficient oxygen in the Baeyer–Villiger oxidation of 6-keto steroids. In fact, in the presence of C-3 substituents, migration of C-7 is more pronounced than in their absence. Further, the bulk of the C-3 substituent seems to have a pronounced effect on the preferred migratory aptitude of C-7 in relation to C-5, as is evidenced by the behavior of the chloro (**19**) and the bromo (**22**) ketones toward perbenzoic acid.

Experimental Section

All melting points are uncorrected. IR spectra were determined in Nujol with a Perkin-Elmer 237 spectrophotometer. NMR spectra were run in $CDCl_3$ on a Varian A60 instrument with Me_4Si as the internal standard. UV spectra were obtained in methanol with a Beckman DK 2 spectrophotometer. TLC plates were coated with silica gel. A 20% aqueous solution of perchloric acid was used as the spraying agent. Light petroleum refers to a fraction of bp 60–80 °C. Anhydrous sodium sulfate was used as the drying agent. (IR: s, strong; w, weak. NMR: dd, double doublet; d, doublet; br, broad; s, singlet; mc, multiplet centred at; a, axial; e, equatorial.)

6-Oxa-*B*-homo-7-oxo-5α-β-sitostanyl Acetate (*2*) and 7-Oxa-*B*-homo-6-oxo-5α-β-sitostanyl Acetate (3). To a solution of 6-keto-5α-β-sitostanyl acetate (**1**) (obtained by acetylation, nitration, and zinc–acetic acid reduction of β-sitosterol) (2 g) in chloroform (30 mL) was added a chloroform solution of perbenzoic acid (1 molar equiv) and a few crystals of *p*-toluenesulfonic acid monohydrate as catalyst, and the reaction mixture was allowed to stand at room temperature for 1 week. The solvent was removed under reduced pressure and the residue extracted with ether. The ethereal solution was washed successively with water, $NaHCO_3$ solution (5%), and water and dried. Removal of the desiccant and the solvent provided a residue (ca. 2 g) which was chromatographed over silica gel (40 g) (each frac-