TABLE III
PHYSICAL CONSTANTS AND MICROANALYTICAL DATA OF POLYYNES

Compd	Infrared absorption, cm^{-1} $\nu_{C\equiv CH}$	$\nu_{C\equiv C\ Cu}$	Cu salt Dec pt, °C[a]	Registry no.	Microanalytical data (Cu salts), % Found C	Found H	Calcd C	Calcd H
$C_6H_5(-C\equiv C-)_2H$	2110, 2190	2170 (broad)	170	34993-58-3	62.9	2.25	63.7	2.65
$1\text{-}C_{10}H_9(-C\equiv C-)_2H$	2195, 2210	2165	193	34993-59-4	69.0	3.50	69.8	3.74
$1\text{-}C_{10}H_9(-C\equiv C-)_3H$	2220, 2240	2180	165	34993-60-7	72.1	3.00	72.6	3.40
$2\text{-}C_{10}H_9(-C\equiv C-)_2H$	2220, 2180	2280	183	34993-61-8	69.2	3.44	69.8	3.74

[a] The decomposition temperatures were measured by a Du Pont 900 differential thermal analyzer.

acting effect of the ring current on the triple bond cloud in the ethynylarenes plays an important role for the deshielding in the acetylenic proton.

Experimental Section

Solvents and Reagents.—All solvents were dried over Drierite and distilled. 1,2-dibromoacetylene (Eastman Kodak Co.) and 1- and 2-acetylnaphthalenes (K and K Laboratories, Inc.) were purified by distillation.

Instrumental Analyses.—Nmr spectra were obtained on a Varian A-60 instrument. A Perkin-Elmer Model 237 infrared spectrophotometer was used for ir measurements. Mass spectra were obtained on a Hitachi Perkin-Elmer Model RMU 60.

Preparation of Ethynylarenes.—Ethynylbenzene purchased from Aldrich Chemical Co. was purified by distillation. 1- and 2-Ethynylnaphthalenes were prepared from 1- and 2-acetylnaphthalenes, respectively, by conversion to the α-chloroethenyl derivatives and then dehydrochlorination of the chloro derivatives with ethanolic potassium hydroxide: 1-ethynylnaphthalene, bp 135° (20 mm) [lit.[11] bp 143–144° (20 mm)], ir 3300 (C≡CH), 2100 cm^{-1} (C≡C); 2-ethynylnaphthalene, bp 110° (1 mm) [lit.[12] bp 104–107° (1 mm)], ir 3300 (C≡CH), 2100 cm^{-1} (C≡C). 1-Ethynylpyrene was supplied by Professor M. Nakagawa, Osaka University, Japan.

Preparation of 9-Ethynylanthracene.—9-Acetylanthracene was prepared from anthracene in 62% yield by Friedel–Crafts acetylation, mp 76°, ir 1690 cm^{-1} (C=O). A mixture of 110 g (0.50 mol) of 9-acetylanthracene and 228.8 g (1.10 mol) of phosphorous pentachloride in 600 ml of dried benzene was refluxed until the evolution of hydrogen chloride gas ceased (*ca.* 20 hr). The reaction mixture was then cooled and poured over crushed ice. The organic layer was then separated and washed twice with cold water. After drying over anhydrous magnesium sulfate, it was concentrated to about 100 ml and then treated with 600 ml of petroleum ether (bp 30–60°). After the solution was kept in an icebox overnight, the crystalline solid (32 g) separated was collected by filtration and recrystallized from benzene–petroleum ether to afford 9,10-dichloroanthracene, mp 217°, mass spectrum *m/e* 246 (M^+), no depression in mixture melting point with an authentic sample. From the filtrate, 9-(α-chloroethenyl)-anthracene was obtained: 30 g; mp 78° (after three recrystallizations from methanol); ir 1630, 1618 (C=C), 928, 900, 890 cm^{-1}; pmr ($CDCl_3$) τ 3.86 (d, 1H, J_{vic} = 1.6 Hz), 4.48 (d, 1 H, J_{vic} = 1.6 Hz), 2.54, 1.60 ppm (m, 9 H); mass spectrum *m/e* 238 (M^+), 202.

Anal. Calcd for $C_{16}H_{11}Cl$: C, 81.34 H, 4.68. Found: C, 81.45; H, 4.73.

9-(α-Chloroethenyl)anthracene (20 g) was then added portionwise with vigorous stirring to a solution of sodium *tert*-butoxide in *tert*-butyl alcohol, prepared from 18 g of sodium, at room temperature. After 3 hr of gentle reflux, the reaction mixture was left overnight at room temperature in the dark and treated with 200 ml of methanol, followed by the addition of 600 ml of ice-water. It was then extracted thoroughly with benzene. The benzene layer was washed with water and then dried over anhydrous magnesium sulfate. After the solvent was evaporated under vacuum at 30°, the residue was extracted with 1000 ml of petroleum ether. Evaporation of petroleum ether afforded 5 g of 9-ethynylanthracene. It was further purified by recrystallization from petroleum ether as orange-red crystals: mp 110–112°; ir 3250 (C≡CH), 2130 cm^{-1} (C≡C); mass spectrum *m/e* 202 (M^+).

Anal. Calcd for $C_{16}H_{10}$: C, 95.05; H, 4.95. Found: C, 95.17; H, 4.97.

Preparation of Di- and Triynes.—The syntheses were carried out by coupling reactions of the corresponding copper acetylides with bromoacetylene in DMF.[13] The di- and triynes obtained (Table III) were isolated, purified, and characterized as the copper salts. Free acetylenic compounds were isolated from the copper salts by treatment with aqueous hydrochloride. The following is a typical procedure for the reaction. Bromoacetylene was generated by the reaction of 1,2-dibromoacetylene with alcoholic potassium hydroxide and was dissolved in DMF. To this DMF solution of bromoacetylene, copper 1-naphthylacetylide was added and kept in an icebox for 24 hr. The reaction mixture was poured into water and the excess bromoacetylene was allowed to escape by constant stirring. 1-Naphthyldiyne obtained was extracted with ether. The ether extract was added to CuCl and NH_4OH solution under a nitrogen atmosphere. The copper salt was filtered, washed with alcohol and acetone, and dried.

Registry No.—**1**, 536-74-3; **2**, 2949-26-0; **3**, 15727-65-8; **4**, 34993-56-1; **5**, 13752-40-4; 9-(α-chloroethenyl)anthracene, 13752-41-5.

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An Improved Synthesis of Acylated 3-Amino-3-deoxy-D-ribofuranose[1]

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In the synthesis of puromycin a lengthy preparation of the modified sugar moiety is involved and the overall yield[2] from D-xylose to the acylated 3-amino-3-deoxy-D-ribofuranose (**1**) is 5%. We have been interested in the preparation of puromycin with sulfur replacing the oxygen of the sugar ring and in the course of our thinking envisioned a shorter route to the acylated **1** which would make possible a much easier route to the synthesis of natural puromycin. Our shorter procedure leads from D-glucose to the acylated **1** in an overall yield of 29%.

Earlier this laboratory reported the synthesis of 3-azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (**2**) from 1,2:5,6-di-*O*-isopropylidene-α-D-3-*O*-(*p*-tolysulfonyl)-α-D-glucofuranose.[3] When the azido compound **2** is selectively hydrolyzed at 25° with

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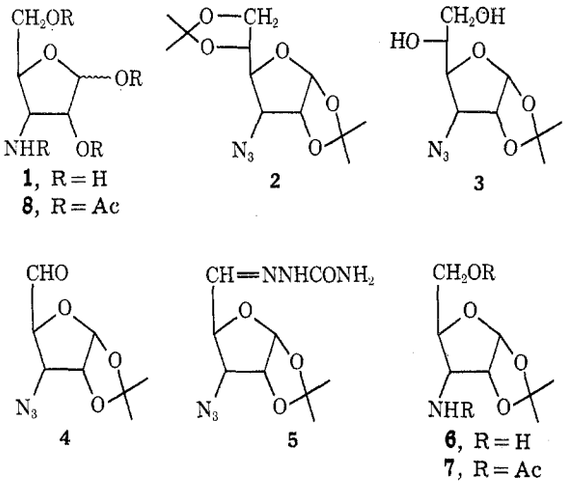

1, R = H
8, R = Ac

2

3

4

5

6, R = H
7, R = Ac

50% aqueous acetic acid, 3-azido-3-deoxy-1,2,*O*-isopropylidene-α-D-allofuranose (**3**) is obtained in 86% yield. The oxidation of **3** with sodium metaperiodate in water containing sodium bicarbonate affords 3-azido-3-deoxy-1,2-*O*-isopropylidene-5-*aldehydo*-α-D-ribopentadialdo-1,4-furanose (**4**) in 91% yield. The infrared spectrum of **4** shows strong absorptions at 2150 (N_3) and 1725 cm^{-1} (CHO) and none for the hydroxyl group. The aldehyde **4** gives a crystalline semicarbazone **5**. It is known that sodium borohydride reduces the azido group to the amino group in such solvent systems as 2-propanol[4] or *N*,*N*-dimethylformamide–methanol,[5] but we have found that, when the azido compound **4** is treated with sodium borohydride in water at 25°, the azido group is only partially reduced even after 16 hr, as indicated by the infrared spectrum which shows peaks at 3400 (OH), 2150 (N_3), and 1616 cm^{-1} (NH_2). However, the reduction becomes complete within 2 more hr when the reaction temperature is raised to 80° (bath). The initial lower temperature is desirable to prevent side reactions of the aldehyde group during reduction. The crude 3-amino-3-deoxy-1,2-*O*-isopropylidene-α-D-ribofuranose (**6**) reacts with acetic anhydride in pyridine to give crystalline 3-acetamido-3-deoxy-5-*O*-acetyl-1,2-*O*-isopropylidene-α-D-ribofuranose (**7**) in 98% yield based on aldehyde **4**. Acetolysis of **7** gives mainly the β anomer of 1,2,5-tri-*O*-acetyl-3-acetamido-3-deoxy-D-ribofuranose (**8**) isolable in 82% yield. The nmr spectrum of acetate **8** shows expected H-1 absorption occurring as a singlet at τ 3.85.

Predominant formation of the β-D anomer by acetolysis of 5,6-di-*O*-benzoyl-1,2-*O*-isopropylidene-3-deoxy-3-*C*-methyl-α-D-allofuranose has been reported.[6]

Experimental Section

Purity of products was determined by thin layer chromatography (tlc) on silica gel G[7] coated glass plates[8] irrigated with (a) benzene–ethyl acetate (6:1), (b) chloroform–acetone (9:2), and (c) chloroform–methanol (6:1). Solvent ratios were based on volumes. Melting points were determined on a Fisher-Johns apparatus and were corrected. Evaporations were done under reduced pressure with a bath temperature below 40°. Infrared spectra were obtained with a Perkin-Elmer Model 337 spectrometer and nmr spectra were determined with a Varian A-60 instrument. Optical rotations were measured on a Perkin-Elmer Model 141 polarimeter.

3-Azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (2).—D-Glucose gave 1,2:5,6-*O*-isopropylidene-α-D-glucofuranose in 90% yield on reaction with dry acetone in the presence of phosphoric acid and zinc chloride.[9] The diisopropylidene derivative reacted at 25° for 4 days with *p*-toluenesulfonyl chloride in pyridine to give 1,2:5,6-diisopropylidene-α-D-3-(*p*-tolylsulfonyl)-α-D-glucofuranose in 96% yield. The azido compound **2** was obtained from the tosyl compound in 53% yield by the literature procedure,[3] mp 38–39° (lit.[3,10] mp 38–39°).

3-Azido-3-deoxy-1,2-*O*-isopropylidene-α-D-allofuranose (3).—A solution of 0.8 g of **2** in 20 ml of 50% aqueous acetic acid was kept at 25° for 6 hr, after which acetic acid was neutralized with sodium bicarbonate and the mixture was extracted with chloroform (3 × 3 ml). The dried (Na_2SO_4) extract was evaporated to a syrup which crystallized on trituration with hexane. Recrystallization from ether–hexane gave the azido compound **3** (0.6 g, 86%): mp 76–77°; $[\alpha]^{25}D$ +111° (*c* 1.5, $CHCl_3$); ν_{max}^{Nujol} 3450 (OH) and 2150 cm^{-1} (N_3).

Anal. Calcd for $C_9H_{15}N_3O_5$: C, 44.03; H, 6.17; N, 17.13. Found: C, 44.23; H, 6.41; N, 17.07.

3-Azido-3-deoxy-1,2-*O*-isopropylidene-5-*aldehydo*-α-D-ribopentadialdo-1,4-furanose-5-semicarbazone (5).—The dihydroxy compound **3** (499 mg) was dissolved in 25 ml of water containing 200 mg of sodium bicarbonate. Sodium metaperiodate (950 mg) was then added in several portions with stirring. Progress of the reaction was monitored by tlc using the solvent system b. When the reaction was complete, the mixture was extracted with chloroform (3 × 25 ml). The dried (Na_2SO_4) extract was evaporated to give 3-azido-3-deoxy-1,2-*O*-isopropylidene-5-*aldehydo*-α-D-ribopentadialdo-1,4-furanose (**4**) (400 mg, 91%), which was homogeneous by tlc with the solvent system b: ν_{max} film 2150 (N_3), 1725 cm^{-1} (CHO).

A 100-mg portion of **4** was treated with a solution of 150 mg of semicarbazide hydrochloride and 220 mg of sodium acetate in 5 ml of water. On cooling crystals separated which were extracted with chloroform. The dried (Na_2SO_4) extract was evaporated to a crystalline residue which was recrystallized from chloroform–hexane to give 105 mg of the semicarbazone **5**, mp 170°, $[\alpha]^{25}D$ +187° (*c* 1.5, $CHCl_3$).

Anal. Calcd for $C_9H_{14}N_6O_4$: C, 39.99; H, 5.22; N, 31.10. Found: C, 40.09; H, 5.23; N, 30.97.

3-Acetamido-3-deoxy-5-*O*-acetyl-1,2-*O*-isopropylidene-α-D-ribofuranose (7).—The crude aldehyde **4** (300 mg) was taken up in 20 ml of water, 360 mg of sodium borohydride was added in several portions, and the mixture was stirred at 25° for 16 hr. A small portion was extracted with chloroform and an ir spectrum of the extract showed peaks at 3450 (OH), 2150 (N_3), and 1615 cm^{-1} (NH_2). The reaction temperature was then raised to 80° (bath) and 360 mg more of sodium borohydride was added. Within 2 hr the reaction was complete. The mixture was cooled, neutralized with acetic acid, and extracted with chloroform (3 × 25 ml). The dried extract was evaporated to give 3-amino-3-deoxy-1,2-*O*-isopropylidene-α-D-ribofuranose (**6**) (280 mg) as a syrup which was homogeneous by tlc with solvent b, ν_{max} film 3400 (OH) and 1615 cm^{-1} (NH_2) but none at 2150 cm^{-1}. The crude amino compound **6** (280 mg) was taken up in 3 ml of pyridine and 1.5 ml of acetic anhydride and kept at 25° for 16 hr. The mixture was poured into 20 g of ice and water and extracted with chloroform (3 × 15 ml). The extract was washed with sodium bicarbonate solution, dried (Na_2SO_4), and evaporated to a crystalline residue which was recrystallized from ether–hexane to give the acetyl derivative **7** (380 mg): mp 165°; ν_{max}^{Nujol} 3440 (NH), 1740 (OAc), and 1680 cm^{-1} (CONH); $[\alpha]^{25}D$ +101° (*c* 1.5, $CHCl_3$).

Anal. Calcd for $C_{12}H_{19}NO_6$: C, 52.72; H, 7.00; N, 5.12. Found: C, 52.92; H, 6.98; N, 5.04.

1,2,5-Tri-*O*-acetyl-3-acetamido-3-deoxy-β-D-ribofuranose (8).—A solution of 4.5 ml of acetic anhydride, 4.5 ml of acetic acid, and 0.25 ml of concentrated sulfuric acid was added at 0° to 400 mg of the isopropylidene derivative **7** and the resulting solution was kept at 0° for 3 days. The reaction mixture was

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then stirred with 5 g of sodium acetate, diluted with 30 ml of water, and extracted with chloroform. The extract was washed with saturated sodium bicarbonate solution, dried (Na_2SO_4), and evaporated to a syrup which was crystallized from ethyl acetate–heptane to give the acetyl derivative **8** (380 mg, 82%): mp 102–103°; ν_{max}^{Nujol} 3440 (NH), 1740 (OAc), and 1680 cm^{-1} (CONH); nmr ($CDCl_3$) τ 3.85 (s, due to H-1), 4.9 (d, H-2, $J_{2,3}$ = 5 Hz), 7.85, 7.90, 7.91, and 8.0 (due to 12 Ac protons); $[\alpha]^{25}D$ +44° (*c* 1.5, $CHCl_3$).

Anal. Calcd for $C_{13}H_{19}NO_8$: C, 49.18; H, 6.04; N, 4.41. Found: C, 49.39; H, 6.31; N, 4.42.

Registry No.—**3**, 35085-25-7; **4**, 35085-26-8; **5**, 35085-27-9; **6**, 14125-95-2; **7**, 29881-54-7; **8**, 35085-30-4.

4-Phenyl-1,2,3,6-tetrahydropyridines in the Prins Reaction. Examples of a Cis Steric Course

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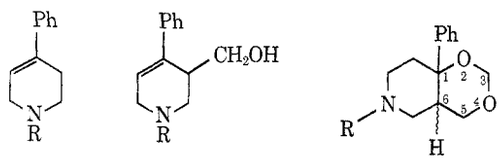
Schmidle and Mansfield[3] reported that the acid-catalyzed addition of formaldehyde to 1-substituted 4-phenyl-1,2,3,6-tetrahydropyridines (**1**) gave the corresponding 3-hydroxymethyltetrahydropyridines **2**. When this Prins reaction[4] is performed using a 10-fold or larger molar excess of formaldehyde, we find that the novel bicyclic 1,3-dioxanes **3** form in yields above 50%; they are isolated as crystalline hydrohalides. The 100-MHz pmr spectrum of **3a** in deuteriochloroform (Figure 1) shows a pair of doublets near δ 4.83 and 3.7, respectively each of two-proton intensity. The former is assigned to the 3-methylene group as the chemical shifts of the equatorial and axial protons are typical of protons flanked by oxygen atoms in 1,3-dioxanes[5] while the ^2J value is numerically low (~6 Hz), also characteristic of methylene in this environment.[6] The lower field half of the four-line signal near δ 3.7, assigned to the 5-methylene protons, shows clear evidence of vicinal coupling (^3J = 2.5 Hz) but the higher field doublet is merely broadened. The absence of a large



1 **2** **3**

a, R = Me; **b**, R = CH_2Ph; **c**, R = *t*-Bu

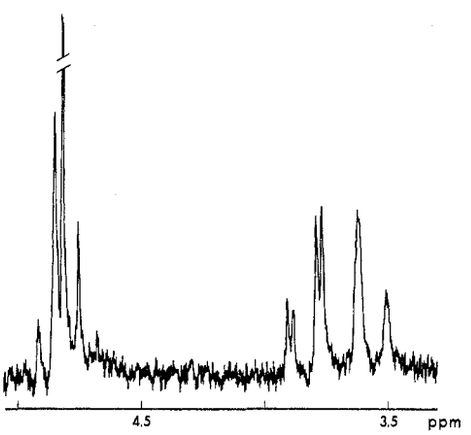
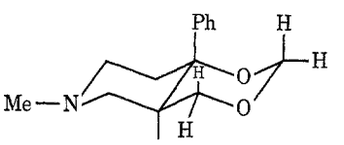
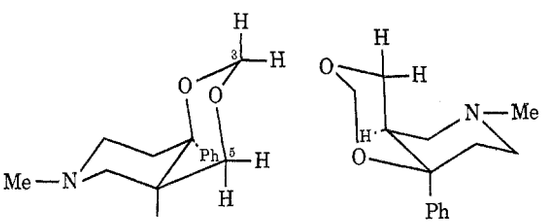


Figure 1.— Part of the 100-MHz pmr spectrum of the 1,3-dioxane **3a** in $CDCl_3$.

^3J value within this signal establishes that neither 5-methylene proton bears a 180° dihedral angle relationship to the 6-methine proton.[7] This conclusion excludes the trans isomer **4** and shows that **3a** is the cis



4



5 **6**

form with the "O inside" (**5**) (opposed to axial hydrogens) rather than "O outside" (**6**)[8] preferred conformation. In **5** the 3 and 5 equatorial protons are linked by a near planar W pathway and their pmr signals display the anticipated long range coupling which broadens the doublets,[7] in support of this stereochemical assignment. Similar evidence was derived from the pmr spectra of **3b** and **3c** (Experimental Section).

While both cis and trans products have been identified from the Prins reaction of acyclic alkenes,[9] the alicyclic derivatives cyclohexene[10] and *trans*-Δ^2-octalin[11] yield trans products exclusively in this procedure. Observation of a cis reaction pathway in the present alicyclic examples is probably a result of the steric demands of the bridgehead phenyl substituent; the same factor will similarly influence the conformation of the

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