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Note

Synthesis of pyrido[2,3-*d*]pyrimidine (5-deazapteridine) *C*-nucleosides from a glycosyl enaminone

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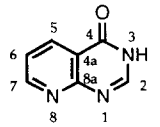
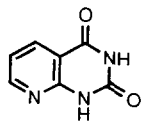
Increasing research has focused on examining the similarity between pyridopyrimidines and pyrimido[2,3-*d*]pyrazines, also referred to as pteridines [1]. Significant antitumor activity against Walker muscular carcinosarcoma in rats has been demonstrated for 4-oxopyrido[2,3-*d*]pyrimidine (**A**) and 2,4-dioxopyrido[2,3-*d*]pyrimidine (**B**) [2]. Robins and his collaborators [3] have synthesized 4-oxo-1-β-D-ribofuranosylpyrido[2,3-*d*]pyrimidine and 2,4-dioxo-8-β-D-ribofuranosylpyrido[2,3-*d*]pyrimidine as potential antitumor and antiviral agents. Despite this, there are no reported examples of the synthesis of *C*-nucleosides of this ring system. The glycosyl enaminone **1** is a key synthetic intermediate in the synthesis of isoxazole [4], quinoline [5], and pyrazolo[1,5-*a*]pyrimidine [6] *C*-nucleosides, and can be obtained readily from 5-hydroxy-5-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)furan-2(5*H*)-one by our previously published procedure [7]. We wish to report here the utilization of **1** in the synthesis of pyrido[2,3-*d*]pyrimidine (5-deazapteridine) *C*-nucleosides.



(A)



(B)

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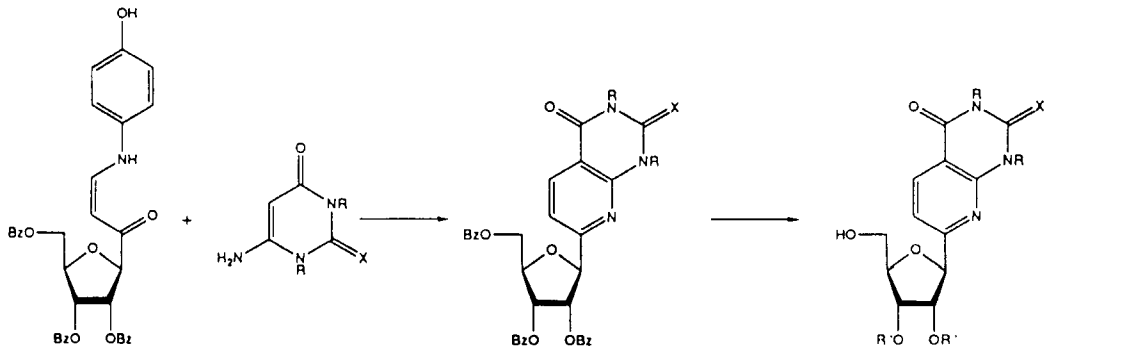
Cyclocondensation of the glycosyl enaminone **1** with 6-aminouracil in trifluoroacetic acid at 70 °C for 8 h gave 2,4-dioxo-7-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)pyrido-[2,3-*d*]pyrimidine (**2**) in 64% yield. The lack of an aromatic singlet in the ^{1}H NMR spectrum of **2** indicates that cyclization must involve C-5 of the original pyrimidine. The appearance of two aromatic doublets and D_2O-exchangeable broad singlets at δ 9.86 and 10.52 corresponding to the ring NH groups is consistent with the assigned structure. Variation in the reaction temperature, time, and solvent did not improve the yield. When **1** was treated with 4-amino-1,3-dimethyluracil in acetic acid at 50 °C, 1,3-dimethyl-2,4-dioxo-7-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)pyrido[2,3-*d*]pyrimidine (**3**) was obtained in 87% yield. The enaminone **1** and 4-amino-6-hydroxy-2-mercaptopyrimidine were heated in trifluoroacetic acid at 60 °C for 7 h. Following purification on silica gel, 4-oxo-2-thioxo-7-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)pyrido[2,3-*d*]pyrimidine (**4**) was isolated in 77% yield. Debenzoylation of compounds **2**, **3**, and **4** with methanolic sodium carbonate afforded the deprotected compounds **5**, **6**, and **7**, which were assigned an anomeric configuration based on the difference in the chemical shifts of the two methyl signals of the corresponding 2′,3′-*O*-isopropylidene derivatives (**8**, **9**, and **10**). The ^{1}H NMR chemical shift differential value ($\Delta\delta$) of the methyl groups (0.21, 0,22, and 0.22 ppm, respectively) is indicative of β stereochemistry in accordance with Imbach's rule [8] (< 0.15 and > 0.15 ppm for the α and β anomers, respectively). This indicates that the β-ribofurano configuration was preserved during the reaction sequence (Scheme 1).

On the other hand, cyclocondensation of **1** with 6-amino-4-oxopyrimidine under similar reaction conditions did not produce a *C*-nucleoside of type **A**. We have prepared a type-**A** *C*-nucleoside from **10** in three steps as described below. Compound **10** was treated with methyl iodide in water to afford 7-(2,3-*O*-isopropylidene-β-D-ribofuranosyl)-2-methylthio-4-oxopyrido[2,3-*d*]pyrimidine (**11**) in 98% yield. The *N*-methylated compound was not formed in measurable amounts. Raney nickel dethiation of **11** gave 7-(2,3-*O*-isopropylidene-β-D-ribofuranosyl)-4-oxopyrido[2,3-*d*]pyrimidine (**12**) in 69% yield. The absence of the 2-CH_3S group was evident in the ^{1}H NMR spectrum by the disappearance of the peak at δ 2.71 and the appearance of a singlet at δ 8.72. Deacetonation of **11** with toluene-*p*-sulfonic acid (PTSA) in methanol afforded 4-oxo-7-β-D-ribofuranosylpyrido[2,3-*d*]pyrimidine (**13**) in 50% yield. Examination of the biological activities of compounds **5**, **6**, **7**, and **13** is now under investigation.

1. Experimental

Mass spectra were taken on a Hitachi M-80 instrument by direct insertion at 70 eV; fast-atom bombardment (FAB) mass spectra were run on a JMS-HX-110 spectrometer. The ^{1}H and ^{13}C NMR spectra were measured with a JNM-GX-270 or an A-600 (Jeol) spectrometer, with tetramethylsilane as an internal standard. UV spectra were recorded with a Shimazu UV-3100PC spectrophotometer. Optical rotations were measured with a Jasco DIP-370 polarimeter (10-cm cell) at 25 °C. Elemental analyses were carried out by the microanalysis service of the University of Meijo. Analytical TLC was performed on glass plates coated with a 0.5-mm layer of Silica Gel GF_{254} (Merck). The compounds were detected by UV light (254 nm).

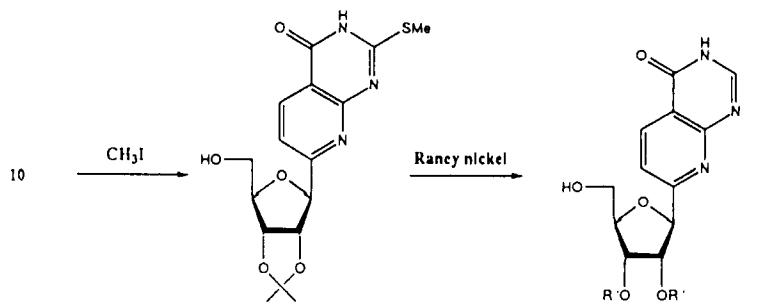


	R	X
1	H	O
	CH_3	O
	H	S

	R	X
2	H	O
3	CH_3	O
4	H	S

	R	R'	X
5	H	H	O
6	CH_3	H	O
7	H	H	S

	R	R',R'	X
8	H	CMe_2	O
9	CH_3	CMe_2	O
10	H	CMe_2	S



11

12 R',R' = CMe_2

13 R' = H

Scheme 1.

2,4-Dioxo-7-(2,3,5-tri-O-benzoyl-β-D-ribofuranosyl)pyrido[2,3-d]pyrimidine (**2**).—A solution of **1** (111.6 mg, 0.19 mmol) and 6-aminouracil (43.2 mg, 0.36 mmol) in CF_3CO_2H (6 mL) was heated at 70 °C for 8 h. The CF_3CO_2H was removed under reduced pressure and the residue was purified by preparative TLC (PLC) with 19:1 $CHCl_3$–MeOH as eluent. This afforded 71 mg (64%) of **2** as a foam; ^1H NMR ($CDCl_3$): δ 4.67 (dd, 1 H, $J_{5'a,4'}$ 4.0, $J_{5'a,5'b}$ 12.1 Hz, H-5'a), 4.86 (m, 1 H, H-4'), 4.93 (dd, 1 H, $J_{5'b,4'}$ 3.7 Hz, H-5'b), 5.56 (d, 1 H, $J_{1',2'}$ 3.7 Hz, H-1'), 5.92 (m, 2 H, H-2',3'), 7.27–8.02 (m, 15 H, Ph), 7.41 (d, 1 H, $J_{5,6}$ 7.7 Hz, H-6), 8.28 (d, 1 H, H-5), 9.86 (br s, 1 H, NH, exchanges with D_2O), 10.52 (br s, 1 H, NH, exchanges with D_2O); ^{13}C NMR ($CDCl_3$): δ 63.9 (C-5'), 72.5, 76.0, 80.0, 83.3 (C-1',2',3',4'), 109.8 (C-4a), 116.9 (C-6), 128.4–133.5 (Ph), 138.5 (C-5), 150.7, 151.4 (C-2,4), 161.7, 164.1, 165.2, 165.4, 166.2 (C-7,8a, C = O). FABMS (nitrobenzyl alcohol as matrix). Found: $[M + H]^+$ *m/z* 608.1654. Calcd for $C_{33}H_{26}N_3O_9$: [M + H] 608.1669.

1,3-Dimethyl-2,4-dioxo-7-(2,3,5-tri-O-benzoyl-β-D-ribofuranosyl)pyrido[2,3-d]pyrimidine (**3**).—A solution of **1** (245.5 mg, 0.4 mmol) and 6-amino-1,3-dimethyluracil (75.2 mg, 0.48 mmol) in AcOH (5 mL) was heated at 50 °C for 17 h. Acetic acid was removed under reduced pressure and the residue was chromatographed on a column of silica gel with 99:1 $CHCl_3$–MeOH as eluent. This afforded 147.9 mg (87%) of **3** as a foam; ^1H NMR ($CDCl_3$): δ 3.46 (s, 3 H, CH_3), 3.56 (s, 3 H, CH_3), 4.56 (dd, 1 H, $J_{5'a,4'}$ 3.9, $J_{5'a,5'b}$ 12.2 Hz, H-5'a), 4.83 (m, 1 H, H-4'), 4.93 (dd, 1 H, $J_{5'b,4'}$ 3.4 Hz, H-5'b), 5.40 (d, 1 H, $J_{1',2'}$ 5.2 Hz, H-1'), 5.93 (dd, 1 H, $J_{2',3'} = J_{3',4'} = 5.2$ Hz, H-3'), 6.09 (dd, 1 H, H-2'), 7.34–8.03 (m, 16 H, Ph, H-6), 8.37 (d, 1 H, $J_{5,6}$ 7.8 Hz, H-5); ^{13}C NMR ($CDCl_3$): δ 28.4, 29.4 (CH_3), 63.5 (C-5'), 72.6, 75.6, 80.3, 83.3 (C-1',2',3',4'), 110.2 (C-4a), 116.3 (C-6), 128.3–133.5 (Ph), 138.7 (C-5), 150.4, 151.3 (C-2,4), 160.9, 162.7, 165.2, 165.4, 166.0 (C-7,8a, C = O). FABMS (nitrobenzyl alcohol as matrix). Found: $[M + H]^+$ *m/z* 636.1965. Calcd for $C_{35}H_{30}N_3O_9$: [M + H] 636.1982.

4-Oxo-2-thioxo-7-(2,3,5-tri-O-benzoyl-β-D-ribofuranosyl)pyrido[2,3-d]pyrimidine (**4**).—A solution of **1** (300.4 mg, 0.5 mmol) and 4-amino-6-hydroxy-2-mercaptopyrimidine (95.7 mg, 0.6 mmol) in CF_3CO_2H (6 mL) was heated at 60 °C for 7 h. The CF_3CO_2H was removed under reduced pressure and the residue was chromatographed on a column of silica gel with 3:1 $CHCl_3$–hexane as eluent. This afforded 236.6 mg (76.7%) of **4** as a foam; ^1H NMR ($CDCl_3$): δ 4.58 (dd, 1 H, $J_{5'a,4'}$ 4.0, $J_{5'a,5'b}$ 12.1 Hz, H-5'a), 4.83 (m, 1 H, H-4'), 4.94 (dd, 1 H, $J_{5'b,4'}$ 3.4 Hz, H-5'b), 5.51 (d, 1 H, $J_{1',2'}$ 4.7 Hz, H-1'), 5.87 (dd, 1 H, $J_{2',3'} = J_{3',4'} = 4.7$ Hz, H-3'), 6.02 (dd, 1 H, H-2'), 7.32–8.00 (m, 15 H, Ph), 7.47 (d, 1 H, $J_{5,6}$ 7.7 Hz, H-6), 8.27 (d, 1 H, H-5), 9.84 (br, 1 H, NH, exchanges with D_2O), 10.56 (br, 1 H, NH, exchanges with D_2O); ^{13}C NMR ($CDCl_3$): δ 63.5 (C-5'), 72.3, 75.9, 80.3, 83.3 (C-1',2',3',4'), 111.2 (C-4a), 118.4 (C-6), 128.4–133.6 (Ph), 138.3 (C-5), 150.7 (C-4), 158.7, 164.6, 165.2, 165.4, 166.1 (C-7,8a, C = O), 174.8 (C = S). FABMS (nitrobenzyl alcohol as matrix). Found: $[M + H]^+$ *m/z* 624.1404. Calcd for $C_{33}H_{26}N_3O_8S$: [M + H] 624.1440.

General procedure for the deprotection.—Methanolic sodium carbonate (0.5 mL, 0.4 mmol) was added to the protected *C*-nucleoside (0.04 mmol) in MeOH (2 mL). The mixture was kept at room temperature for 5 h, and evaporated under reduced pressure. The residue was purified by PLC to afford the free *C*-nucleoside.

2,4-Dioxo-7-β-D-ribofuranosylpyrido[2,3-d]pyrimidine (**5**).—Colourless needles

(34%); mp 178–181 °C (from MeOH); $[\alpha]_D$ −0.2° (*c* 0.3, Me_2SO); λ_{max}^{MeOH} 207 and 302 nm (log ε 4.3 and 3.9); ^1H NMR [$(CD_3)_2SO$]: δ 3.54 (dd, 1 H, $J_{5'a,4'}$ 3.7, $J_{5'a,5'b}$ 12.4 Hz, H-5'a), 3.66 (dd, 1 H, $J_{5'b,4'}$ 3.0 Hz, H-5'b), 3.90 (m, 3 H, H-2',3',4'), 4.66 (d, 1 H, $J_{1',2'}$ 4.4 Hz, H-1'), 7.03 (d, 1 H, $J_{5,6}$ 7.7 Hz, H-6), 8.04 (d, 1 H, H-5); ^{13}C NMR [$(CD_3)_2SO$]: δ 61.4 (C-5'), 70.8, 76.8, 84.3, 85.1 (C-1',2',3',4'), 108.8 (C-4a), 115.6 (C-6), 136.9 (C-5), 150.6, 152.0 (C-2,4), 162.2, 166.8 (C-7,8a); FABMS (glycerol as matrix). Found: $[M + H]^+$ *m/z* 296.0910. Calcd for $C_{12}H_{14}N_3O_6$: [M + H] 296.0883. Anal. Calcd for $C_{12}H_{13}N_3O_6$: C, 48.82; H, 4.44; N, 14.23. Found: C, 48.65; H, 4.38; N, 14.13.

1,3-Dimethyl-2,4-dioxo-7-(β-D-ribofuranosyl)pyrido[2,3-d]pyrimidine (**6**).—Colourless needles (74.5%); mp 165–166 °C (from MeOH); $[\alpha]_D$ +1.5° (*c* 0.3, Me_2SO); λ_{max}^{MeOH} 211 and 305 nm (log ε 4.2 and 4.0); ^1H NMR [$(CD_3)_2SO$]: δ 3.29 (s, 3 H, CH_3), 3.57 (m, 4 H, CH_3, H-5'a), 3.66 (m, 1 H, H-5'b), 3.91 (m, 2 H, H-3',4'), 4.02 (br s, 1 H, H-2'), 4.78 (d, 1 H, $J_{1',2'}$ 5.2 Hz, H-1'), 4.84, 4.98, 5.21 (br, 3 H, OH, exchanges with D_2O), 7.52 (d, 1 H, $J_{5,6}$ 7.8 Hz, H-6), 8.34 (d, 1 H, H-5); ^{13}C NMR [$(CD_3)_2SO$]: δ 28.0, 29.0 (CH_3), 61.7 (C-5'), 71.1, 76.8, 84.5, 85.1 (C-1',2',3',4'), 109.2 (C-4a), 116.0 (C-6), 137.6 (C-5), 150.0, 151.0 (C-2,4), 160.7, 166.1 (C-7,8a). FABMS (nitrobenzyl alcohol as matrix). Found: $[M + H]^+$ *m/z* 324.1214. Calcd for $C_{14}H_{18}N_3O_6$: [M + H] 324.1196. Anal. Calcd for $C_{14}H_{17}N_3O_6$: C, 52.01; H, 5.30; N, 13.00. Found: C, 51.90; H, 5.46; N, 12.64.

4-Oxo-7-β-D-ribofuranosyl-2-thioxopyrido[2,3-d]pyrimidine (**7**).—Pale-yellow needles (89.4%); mp 256 °C (dec) (from MeOH); $[\alpha]_D$ +57.9° (*c* 0.2, Me_2SO); λ_{max}^{MeOH} 237, 282, and 318 nm (log ε 3.9, 4.5, and 4.1); ^1H NMR [$(CD_3)_2SO$]: δ 3.53 (dd, 1 H, $J_{5'a,4'}$ 3.7, $J_{5'a,5'b}$ 12.1 Hz, H-5'a), 3.68 (dd, 1 H, $J_{5'b,4'}$ 3.0 Hz, H-5'b), 3.88 (m, 1 H, H-4'), 3.93 (dd, 1 H, $J_{2',3'} = J_{3',4'} = 4.7$ Hz, H-3'), 4.01 (dd, 1 H, $J_{1',2'}$ 4.7 Hz, H-2'), 4.68 (d, 1 H, H-1'), 7.11 (d, 1 H, $J_{5,6}$ 8.1 Hz, H-6), 8.08 (d, 1 H, H-5); ^{13}C NMR (CD_3OD): δ 64.1 (C-5'), 73.6, 79.1, 87.0, 87.3 (C-1',2',3',4'), 113.0 (C-4a), 119.4 (C-6), 139.1 (C-5), 153.5 (C-4), 162.4, 169.5 (C-7,8a), 178.6 (C = S). FABMS (glycerol as matrix). Found: $[M + H]^+$ *m/z* 312.0643. Calcd for $C_{12}H_{14}N_3O_5S$: [M + H] 312.0654. Anal. Calcd for $C_{12}H_{13}N_3O_5S \cdot 0.25H_2O$: C, 45.70; H, 4.30; N, 13.08. Found: C, 45.64; H, 4.31; N, 13.31.

7-(2,3-O-Isopropylidene-β-D-ribofuranosyl)-2,4-dioxopyrido[2,3-d]pyrimidine (**8**).—To a solution of deprotected *C*-nucleoside (**5**) (6.3 mg, 0.02 mmol) in acetone (1 mL) was added PTSA (5 mg) and the mixture was stirred at room temperature for 4 h. The reaction mixture was neutralized with satd aq $NaHCO_3$, and the solvent was evaporated. The residue was purified by PLC with 9:1 $CHCl_3$–MeOH as eluent. This afforded 6.1 mg (85%) of **8** as a foam; ^1H NMR (CD_3OD): δ 1.36, 1.57 (each s, each 3 H, CMe_2), 3.64 (dd, 1 H, $J_{5'a,4'}$ 5.1, $J_{5'a,5'b}$ 11.7 Hz, H-5'a), 3.69 (dd, 1 H, $J_{5'b,4'}$ 4.4 Hz, H-5'b), 4.21 (m, 1 H, H-4'), 4.72 (dd, 1 H, $J_{3',4'}$ 3.4, $J_{2',3'}$ 6.6 Hz, H-3'), 4.91 (dd, 1 H, $J_{1',2'}$ 3.9 Hz, H-2'), 5.00 (d, 1 H, H-1'), 7.46 (d, 1 H, $J_{5,6}$ 8.1 Hz, H-6), 8.33 (d, 1 H, H-5). FABMS (nitrobenzyl alcohol as matrix). Found: $[M + H]^+$ *m/z* 336.1171. Calcd for $C_{15}H_{18}N_3O_6$: [M + H] 336.1196.

7-(2,3-O-Isopropylidene-β-D-ribofuranosyl)-1,3-dimethyl-2,4-dioxopyrido[2,3-d]pyrimidine (**9**).—This compound was prepared from **6** as described above for **8**: foam, 72%; ^1H NMR (CD_3OD): δ 1.37, 1.59 (each s, each 3 H, CMe_2), 3.40 (s, 3 H,

N-CH_3), 3.61–3.72 (m, 5 H, N-CH_3, H-5′), 4.22 (m, 1 H, H-4′), 4.74 (dd, 1 H, $J_{2',3'} = J_{3',4'} = 6.5$ Hz, H-3′), 4.93 (dd, 1 H, $J_{1',2'}$ 3.7 Hz, H-2′), 5.03 (d, 1 H, H-1′), 7.47 (d, 1 H, $J_{5,6}$ 7.8 Hz, H-6), 8.37 (d, 1 H, H-5). FABMS (nitrobenzyl alcohol as matrix). Found: $[M + H]^+$ m/z 364.1506. Calcd for $C_{17}H_{22}N_3O_6$: [M + H] 364.1508.

*7-(2,3-*O*-Isopropylidene-β-*D*-ribofuranosyl)-4-oxo-2-thioxopyrido[2,3-*d*]pyrimidine* (**10**).—This compound was prepared from **7** as described above for **8**: foam, 63.7%; ^{1}H NMR (CD_3OD): δ 1.35, 1.57 (each s, each 3 H, CMe_2), 3.65 (m, 2 H, H-5′), 4.21 (m, 1 H, H-4′), 4.71 (dd, 1 H, $J_{3',4'}$ 3.4, $J_{2',3'}$ 6.4 Hz, H-3′), 4.91 (dd, 1 H, $J_{1',2'}$ 4.0 Hz, H-2′), 5.01 (d, 1 H, H-1′), 7.52 (d, 1 H, $J_{5,6}$ 8.1 Hz, H-6), 8.34 (d, 1 H, H-5). FABMS (glycerol as matrix). Found: $[M + H]^+$ m/z 352.0982. Calcd for $C_{15}H_{18}N_3O_5S$: [M + H] 352.0967.

*7-(2,3-*O*-Isopropylidene-β-*D*-ribofuranosyl)-2-methylthio-4-oxopyrido[2,3-*d*]pyrimidine* (**11**).—Methyl iodide (28.9 mg, 0.2 mmol) was added to a stirred solution of **10** (53.1 mg, 0.15 mmol) and $NaHCO_3$ (100 mg) in 1:1 acetone–water (3 mL). The mixture was kept at room temperature for 30 min. The reaction mixture was neutralized with AcOH and extracted with $CHCl_3$ (3 × 10 mL). The extracts were combined, washed with water, dried over $MgSO_4$, and evaporated to give a syrup. The residual syrup was purified by PLC with 95:5 $CHCl_3$–MeOH as eluent. This afforded 54.4 mg (98.5%) of **11** as a foam; ^{1}H NMR (CD_3OD): δ 1.37, 1.64 (each s, each 3 H, CMe_2), 2.71 (s, 3 H, S-CH_3), 3.76 (dd, 1 H, $J_{5'a,4'}$ 2.2, $J_{5'a,5'b}$ 12.5 Hz, H-5′a), 4.06 (dd, 1 H, $J_{5'b,4'}$ 2.0 Hz, H-5′b), 4.53 (m, 1 H, H-4′), 4.89 (dd, 1 H, $J_{1',2'}$ 3.7, $J_{2',3'}$ 6.0 Hz, H-2′), 5.02 (dd, 1 H, $J_{3',4'}$ 2.0 Hz, H-3′), 5.19 (d, 1 H, H-1′), 7.37 (d, 1 H, $J_{5,6}$ 8.1 Hz, H-6), 8.56 (d, 1 H, H-5); ^{13}C NMR ($CDCl_3$): δ 13.6 (S-CH_3), 25.3, 27.4 (CMe_2), 63.8 (C-5′), 83.0, 86.8, 87.3, 87.7 (C-1′,2′,3′,4′), 113.5 (C-4a), 114.7 (CMe_2), 119.6 (C-6), 137.9 (C-5), 158.2 (C-4), 161.3, 162.7, 167.2 (C-2,7,8a). FABMS (nitrobenzyl alcohol as matrix). Found: $[M + H]^+$ m/z 366.1123. Calcd for $C_{16}H_{20}N_3O_5S$: [M + H] 366.1124.

*7-(2,3-*O*-Isopropylidene-β-*D*-ribofuranosyl)-4-oxopyrido[2,3-*d*]pyrimidine* (**12**).—To a solution of **10** (55.7 mg, 0.15 mmol) in 1:1 acetone–water (6 mL) and 28% ammonia (0.4 mL) was added 300 mg (wet weight) of Raney Ni and the suspension was refluxed for 3 h. The mixture was filtered through Celite and the filtrate was evaporated in vacuo. The residue was purified by PLC with 92:8 $CHCl_3$–MeOH as eluent. This afforded 32.8 mg (69%) of **12** as a foam; ^{1}H NMR ($CDCl_3$): δ 1.37, 1.64 (each s, each 3 H, CMe_2), 3.87 (dd, 1 H, $J_{5'a,4'}$ 2.7, $J_{5'a,5'b}$ 12.5 Hz, H-5′a), 4.10 (dd, 1 H, $J_{5'b,4'}$ 2.2 Hz, H-5′b), 4.54 (m, 1 H, H-4′), 4.85 (dd, 1 H, $J_{1',2'}$ 3.8, $J_{2',3'}$ 6.0 Hz, H-2′), 5.04 (dd, 1 H, $J_{3',4'}$ 2.0 Hz, H-3′), 5.19 (d, 1 H, H-1′), 7.46 (d, 1 H, $J_{5,6}$ 8.1 Hz, H-6), 8.60 (d, 1 H, H-5), 8.72 (s, 1 H, H-2); ^{13}C NMR ($CDCl_3$): δ 25.3, 27.4 (CMe_2), 63.5 (C-5′), 83.0, 86.7, 87.2, 87.5 (C-1′,2′,3′,4′), 113.8 (CMe_2), 117.8 (C-4a), 120.9 (C-6), 137.9 (C-5), 149.7 (C-2), 158.4 (C-7), 161.8 (C-8a), 166.8 (C-4). FABMS (glycerol as matrix). Found: $[M + H]^+$ m/z 320.1255. Calcd for $C_{15}H_{18}N_3O_5$ [M + H] 320.1246.

*4-Oxo-7-β-*d*-ribofuranosylpyrido[2,3- d]pyrimidine* (**13**).—To a solution of **12** (16.1 mg, 0.05 mmol) in MeOH was added PTSA (5 mg), and the resulting solution was stirred at room temperature for 15 h. The solvent was removed under reduced pressure, and the residue was chromatographed on a column of silica gel with 9:1 EtOAc–MeOH as eluent. This afforded 7.0 mg (50%) of **13** as colorless crystals; mp 241–242 °C (from MeOH); $[\alpha]_D$ +34.7° (c 0.1, Me_2SO); λ_{max}^{MeOH} 219 and 293 nm (log ε 3.8 and 3.3); ^{1}H

NMR [$(CD_3)_2SO$]: δ 3.56 (m, 1 H, H-5′a), 3.68 (m, 1 H, H-5′b), 3.91 (m, 2 H, H-3′,4′), 4.02 (m, 1 H, H-2′), 4.82 (d, 1 H, $J_{1',2'}$ 4.8 Hz, H-1′), 4.92 (d, 1 H, $J_{3',OH}$ 5.7 Hz, 3′-OH, exchanges with D_2O), 4.97 (t, 1 H, $J_{5',OH}$ 5.7 Hz, 5′-OH, exchanges with D_2O), 5.22 (d, 1 H, $J_{2',OH}$ 5.7 Hz, 2′-OH, exchanges with D_2O), 7.74 (d, 1 H, $J_{5,6}$ 8.1 Hz, H-6), 8.30 (s, 1 H, H-2), 8.47 (d, 1 H, H-5), 12.51 (br s, 1 H, NH, exchanges with D_2O); ^{13}C NMR [$(CD_3)_2SO$]: δ 61.8 (C-5′), 71.2, 77.3, 84.9, 85.4 (C-1′,2′,3′,4′), 117.2 (C-4a), 120.4 (C-6), 136.8 (C-5), 149.1 (C-2), 158.4, 161.7, 167.9 (C-4,7,8a). FABMS (nitrobenzyl alcohol as matrix). Found: $[M + H]^+$ m/z 280.0930. Calcd for $C_{12}H_{14}N_3O_5$: [M + H] 280.0933. Anal. Calcd for $C_{12}H_{13}N_3O_5 \cdot 0.25H_2O$: C, 50.85; H, 4.77; N, 14.69. Found: C, 50.79; H, 4.80; N, 14.81.

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