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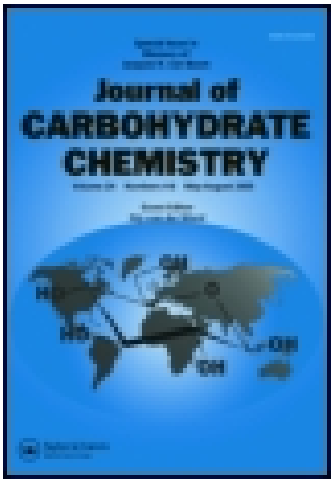

Journal of Carbohydrate Chemistry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lcar20

An Efficient Synthesis and Physico-Chemical Properties OF 2′-O-d-Ribofuranosylnuleosides, Minor tRNA Components

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Published online: 21 Aug 2006.

To cite this article: Sergey N. Mikhailov , Ekaterina V. Efimtseva , Galina V. Gurskaya , Marina V. Fomitcheva , Sergey V. Meshkov , Valery E. Zavodnik , André De Bruyn , Gerard Janssen , Jef Rozenski & Piet Herdewijn (1997) An Efficient Synthesis and Physico-Chemical Properties OF 2′-O-d-Ribofuranosylnuleosides, Minor tRNA Components, Journal of Carbohydrate Chemistry, 16:1, 75-92

To link to this article: http://dx.doi.org/10.1080/07328309708006511

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J. CARBOHYDRATE CHEMISTRY, 16(1), 75-92 (1997)

AN EFFICIENT SYNTHESIS AND PHYSICO-CHEMICAL PROPERTIES OF 2'-*O*-D-RIBOFURANOSYLNUCLEOSIDES, MINOR tRNA COMPONENTS

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Received February 1, 1996 - Final Form October 10, 1996

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ABSTRACT

A high yield preparation of 9-(2-*O*-β-D-ribofuranosyl-β-D-ribofuranosyl)adenine, guanine- and the pyrimidine analogs (cytosine, thymine and uracil base moiety) has been achieved, and the conformational properties of the ring systems were investigated using NMR spectroscopy and X-ray.

INTRODUCTION

Disaccharide nucleosides are important structural elements of several antibiotics such as amicetin,[1] hikizimycin,[2] thuringiensin,[3] tunicamycin[4] and others (for reviews see

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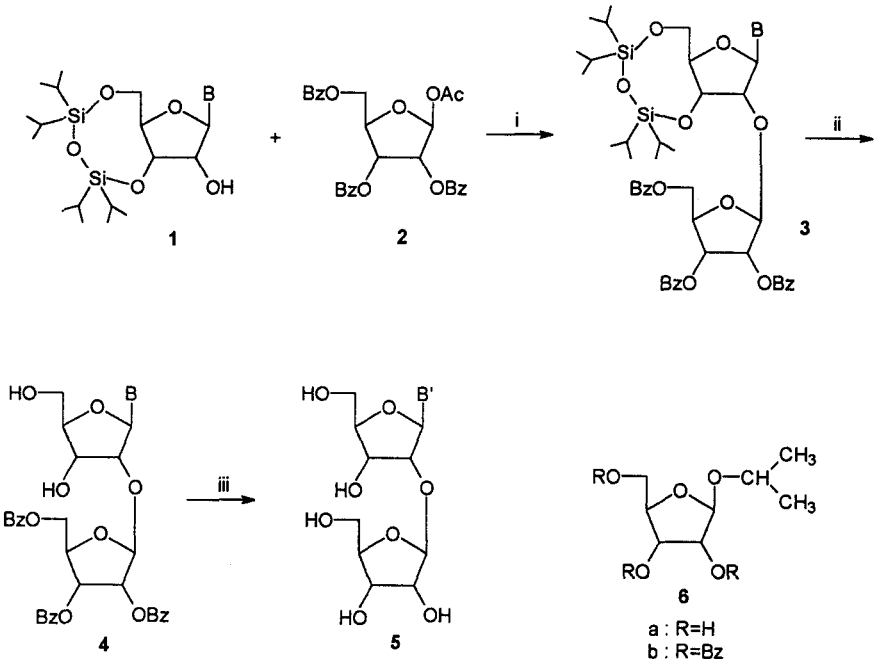
ref. 5 and ref. 6). Recently some new derivatives[7,8] of disaccharide nucleosides have been isolated from natural products andshown to possess interesting biological activities. Disaccharide nucleosides have been prepared either by coupling of suitably blocked disaccharides with nucleic bases or by condensation of protected nucleosides with monosaccharide. Most of complex nucleoside antibiotics have been prepared using the first route. This route is rather lengthy and it may be shortened in some cases starting from natural nucleosides. Several attempts had been made to use classical methods of glycosidic bond formation with blocked nucleosides as alcohol component. The yields of these reactions were usually very low (20-30 %) due to a formation of several by-products.[5] Till now no general high yielding synthetic procedure to disaccharide nucleosides from natural nucleosides has been developed and their physico-chemical and biological properties have not been studied systematically.

RESULTS AND DISCUSSION

Here we present our results (for a preliminary report see ref. 9) on the preparation of *O*-β-D-ribofuranosyl-nucleosides starting from readily available 3',5'-*O*-blocked *N*-acylribonucleosides **1a-e**[10] and a slight excess of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose **2** in the presence of tin tetrachloride. The glycosylation reaction proceeded stereospecifically with the formation of the β-D-glycosidic bond. In disaccharide nucleosides **3a-e** the coupling constants ($J_{1',2'}$) in the ribose moiety are less than 0.5 Hz. The yields of **3a-e** were in the range from 70% to 80%, which is higher than reported for similar condensation reactions between blocked nucleosides and monosaccharides.[5] The reaction conditions are near the same as earlier reported for the preparation of alkyl ribonucleosides.[11] The ribosylation of **1a** and **1e** proceeded respectively for 7 h and 16 h at 0 °C, much slower than in the case of pyrimidine derivatives.

The silyl group was selectively deblocked to yield partially protected **4a-e**, which may be used for further modification. Deblocking with ammonia in methanol gave free disaccharide nucleosides **5a-e** in high overall yield. The structure of the compounds was proven by NMR and mass spectroscopy. Tentative assignments in ^{13}C NMR spectra were made by comparison with starting compounds **1a-e** and model riboside **6a** and its tribenzoate derivative **6b**. It should be mentioned that adenine disaccharide **5a** and guanine disaccharide **5e** have been isolated from yeast methionine initiator tRNA.[12-15] The adenine derivative **5a** has been prepared previously utilizing near the same approach[16] and by an acid catalyzed condensation of adenosine and D-ribofuranose.[17] Some conformational properties were derived from the ^1H NMR data.



a) B = Ade^{Bz}, b) B = Cyt^{Bz}, c) B = Ura, d) B=Thy, e) B=Gua ^{iBu}.

a) B' = Ade, b) B' = Cyt, c) B' = B = Ura, d) B'=B=Thy, e) B'=Gua.

i : $SnCl_4$, $C_2H_4Cl_2$, 0 °C; ii : Bu_4NF, THF, RT; iii : NH_3, MeOH, RT.

Scheme 1

The chemical shifts of **5a-e** (Table 1) were identified from COSY 45 experiments. For the nucleoside moiety we followed the connectivities starting from H-1'. The glycosidic protons were assigned by comparison of their chemical shifts with reference compounds. Thus the resonance of the proton at the highest frequency is assigned to that of the nucleoside. For the assignment of the resonances of the β-D-ribofuranosyl moiety in the COSY experiment, we could not start from the resonance for H-1' since the coupling constant $J_{1',2'}$ is smaller than the resolution. Therefore we started following the connectivities in the COSY experiment from the resonances of H-5'a and H-5'b. From the NOESY experiment (τm = 80 ms) interesting structural features can be derived.

In compound **5b** the H-5 and H-6 resonances were assigned by comparison with known data. Here the resonances for H-1' and H-5 nearly collapse so that it is difficult to be certain if the NOE contacts observed originate from H-1' or H-5. However, the NOE

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Table 1. ^{1}H NMR Chemical Shifts and coupling constants in D_2O at 20 °C (at 360 MHz).

Compound →	5a		5b[a]		5c		5d		5e		6
moiety →	Ado	Rib	Cyd	Rib	Urd	Rib	Thd	Rib	Guo	Rib	Rib
chemical shifts											
H-8 (H-6)	8.32s		7.816		7.87d		7.66q		8.03		
H-2 (H-5)(CH_3)	8.19s		6.067		5.92d		1.91d				
H-1'	6.12d	5.07s	6.046	5.123	6.04d	5.15s	6.03d	5.12d	6.01d	5.12s	5.10d
H-2'	4.80dd	4.13d	4.376	4.16[c]	4.44dd	4.16d	4.44dd	4.13dd	4.81dd	4.17dd	3.98dd
H-3'	4.55dd	3.99dd	4.338	4.170	4.36dd	4.19dd	4.38dd	4.14dd	4.56dd	4.08dd	4.16dd
H-4'	4.29ddd	3.82ddd	4.116	3.975	4.11ddd	3.99ddd	4.11ddd	3.99ddd	4.26ddd	3.92ddd	3.98ddd
H-5'a	3.92dd	3.32dd	3.883	3.711	3.88dd	3.75dd	3.88dd	3.71dd	3.91dd	3.47dd	3.79dd
H-5'b	3.83dd	2.75dd	3.795	3.373	3.79dd	3.48dd	3.81dd	3.44dd	3.85dd	3.01dd	3.62dd
coupling constants											
5,6			7.6		8.1		1.2				
1',2'	6.4	<0.5	5.1	<0.5[b]	5.0	<0.5	5.5	<0.5	6.3	0.8	1.5
2',3'	5.0	4.5	5.5	4.6[c]	5.4	4.8	5.5	4.7	5.3	4.6	4.8
3',4'	3.3	7.4	4.7	6.8[c]	5.1	6.9	4.7	6.7	3.3	7.3	6.5
4',5'a	2.6	3.7	3.0	3.4	2.9	3.4	3.1	3.6	3.1	3.8	3.5
4',5'b	3.6	6.8	4.4	6.7	4.5	6.6	4.5	6.7	4.1	6.8	6.6
5'a,5'b	-13.0	-12.0	-12.7	-12.2	-12.7	-12.1	-12.7	-12.1	-12.8	-11.9	-12.2

a. Measured at CCRC, Athens, Georgia
b. Not resolved
c. Measurement of exact chemical shift and coupling constants requires higher order analysis. The present data are from a first order approach.

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contacts involved with H-5 and H-6 allow for the conclusion that the conformation about the glycosidic bond is anti (the carbonyl bond pointing away from the ring).

Indeed, important NOE constraints exist between H-5 (from the base) and H-2', H-5'a, H-5'b and H-4'. The latter is probably a diffusion effect caused by the intense NOE effect found for H-5' protons. The NOE constraints between H-6 and both the H-5' protons are weaker than with H-5. No NOE effect is seen between H-6 and H-2' and H-4'. For the conformation about the C4'-C5' bond (γ) we find a discrepancy between the NOE constraint. NOE constraints between H5/6 of the base and H5',5" suggest that the OH group points away from the ring as confirmed by the gt (or ap or t) conformation found by X-ray, while the calculations from the vicinal coupling constants $J_{4',5'a}$ and $J_{4',5'b}$ using the equation proposed by Altona,[18] the gg (or +sc or g^+) rotamer is most prominent by 63% and in this case the OH group hangs over the ring.

$$x_g+ = [13.75 - (3.0 + 4.4)]/10.05 = 0.63$$

The NOE constraint verifies the introduction of the ribose moiety into the 2' position of the nucleoside.

According to ^{1}H NMR data collected, attachment of a ribose moiety to the 2'-position of the nucleoside resulted in a small shift of $S \rightleftharpoons N$ equilibrium towards *S*-conformer. The chemical shifts and coupling constants of pyrimidine disaccharide nucleosides **5b-d** have nearly the same values as in the case of uridine (Urd), thymidine (Thd), cytidine (Cyd) and isopropyl β-D-ribofuranoside **6a**. The anisotropical influence of the purine ring in **5a,e** is much more pronounced not only for the chemical shift of the sugar protons of the nucleoside moiety but also for those of the ribose residues, especially for 5'a and 5'b protons. NOE constraints are observed between base protons and H-5'a and H-5'b of ribose residue.

The three-dimensional structure of Urd-Rib (**5c**) was determined by X-ray analysis (Figure 1). The atomic coordinates are presented in Table 2 and Table 3. An anti-conformation about the *N*-glycosidic bond and g,t-conformations of the exocyclic 5'-CH_2OH and 5"-CH_2OH groups are found in the molecule. The torsion angles χ are (C2-N1-C1'-O4')=-114.6°, γ (C3'-C4'-C5'-O5')=-176.9°, γ(C3"-C4"-C5"-O5")=-177.9°. The conformation of the furanose ring of the uridine residue is C4'-exo ($_4$E) (P=54.6°, Ψ m=36.6°). Atom C4' deviates from the C1', C2', C3' and O4' atoms plane by 0.519 Å. The puckering mode of the ribofuranosyl residue can be classified as C2"-exo-C3"-endo ($_2T^3$). The phase angle of pseudorotation P is 344.4° and degree of pucker Ψm=38.3°. The C2" and C3" atoms are displaced from the plane of C1", C4", O4" atoms by 0.543 and 0.051 Å respectively. It should be mentioned that in the Urd-Rib molecule the 2'-*O*-ribose residue is located near the uracil heterocycle, the distances between the exocyclic

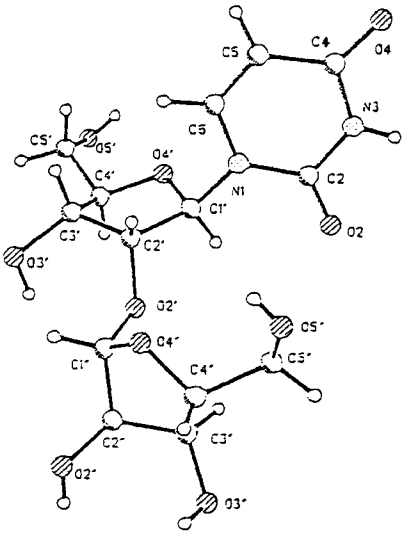

Figure 1. Crystal structure of Urd-Rib.

5'-CH_2OH and 5"-CH_2OH groups and the atoms O2 and C6 are rather similar: 02-05' (6.452 Å), O2-O5" (4.751 Å), C6-C5' (4.537 Å) and C6-C5" (5.448 Å). This corresponds very nicely with the observed NOE effects.

Torsion angles were calculated from H,H coupling constants using the Karplus equation for furanose rings.[18] The results are given in Table 4. Ring puckering from these data were obtained using the computer modelling package HyperChem™ (Release 3, Autodesk Inc.). 1-Ribosylamine was built and minimized using the MM+ algorithm and a restraint was set on the hydrogen torsion angles in order to obtain a molecule corresponding to the NMR data. After minimization the torsion angles for the furanose ring were used for the calculation of the pseudorotation phase angle, P. For compound **5c** the ring puckering for both furanosyl rings (P = 55 for Urd and P = 342 for Rib) is close to the ones observed by X-ray analysis.

The exocyclic torsion angles for both ribose moieties (5'CH_2OH and 5"CH_2OH) are found to be around 60° in solution based up NMR studies but are around 180° in the solid state (X-ray data). The difference observed from the X-ray data may be due to the fact that in the crystal intermolecular hydrogen bonds are formed. Packing of the molecules in the crystal is shown in Figure 2.

The compounds **5a-c** did not show antiviral activity when tested against HSV-1, HSV-2, Vaccinia virus, Vesicular stomatitis virus, Coxsackie virus B4, Polio virus-1, Parainfluenza-3 virus, Reovirus-1, Sindbis virus, Semliki forest virus and HIV-1.

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Table 2. Atom coordinates (x 10^4) and temperature factors (A^2 x 10^3)

Atom	X	Y	Z	U
N(1)	4939(4)	5562(2)	4662(2)	26(1)*
C(2)	3456(5)	4976(2)	3828(2)	33(1)*
N(3)	3712(5)	5000	2485(2)	35(1)*
C(4)	5305(5)	5540(2)	1916(2)	32(1)*
C(5)	6805(6)	6121(2)	2860(3)	37(1)*
C(6)	6567(5)	6118(2)	4166(3)	31(1)*
O(2)	2011(5)	4469(2)	4228(2)	59(1)*
O(4)	5313(4)	5489(2)	699(2)	46(1)*
C(1')	4601(5)	5636(2)	6071(2)	25(1)*
C(2')	7270(4)	5579(2)	7174(2)	23(1)*
C(3')	7406(4)	6419(2)	7903(2)	25(1)*
C(4')	4448(5)	6724(2)	7558(2)	24(1)*
O(4')	3401(3)	6421(2)	6192(2)	31(1)*
O(2')	6868(3)	4924(2)	8037(2)	26(1)*
O(3')	8555(3)	6404(2)	9316(2)	33(1)*
C(5')	4266(5)	7643(2)	7561(3)	31(1)*
O(5')	1521(4)	7938(2)	7310(2)	34(1)*
C(1")	9304(5)	4538(2)	8758(2)	24(1)*
C(2")	8329(5)	3914(2)	9681(2)	26(1)*
C(3")	7466(4)	3207(2)	8670(2)	26(1)*
C(4")	9593(4)	3250(2)	7772(2)	27(1)*
O(2")	10602(3)	3700(2)	10747(2)	32(1)*
O(3")	7186(4)	2431(2)	9244(2)	37(1)*
O(4")	10578(3)	4084(2)	7854(2)	30(1)*
C(5")	8462(6)	3035(2)	6295(3)	38(1)*
O(5")	10501(4)	3051(2)	5487(2)	42(1)*

* Equivalent isotropic U defined as one third of the trace of the orthogonalised U(i,j) tensor.

Table 3. Hydrogen coordinates (x 10^3) and temperature factors (A^2 x 10^2)

Atom	X	Y	Z	U
H(3)	264(7)	464(2)	204(4)	5(1)
H(5)	788(8)	655(3)	260(4)	6(1)
H(6)	762(6)	648(2)	482(3)	4(1)
H(1')	347(6)	522(2)	623(3)	3(1)
H(2')	884(6)	548(2)	676(3)	2(1)
H(3')	854(6)	680(2)	747(3)	3(1)
H(4')	332(5)	647(2)	813(2)	2(1)
H(3')0	746(8)	606(2)	971(4)	5(1)
H(5'1)	528(7)	785(2)	688(3)	2(1)
H(5'2)	512(6)	785(2)	843(3)	4(1)
H(5')0	104(6)	794(2)	651(3)	4(1)
H(1")	1065(5)	495(2)	928(2)	2(1)
H(2")	674(6)	414(2)	1006(3)	4(1)
H(2")0	992(7)	342(2)	1131(4)	6(1)
H(3")	575(5)	334(2)	808(2)	2(1)
H(3")0	868(8)	229(3)	961(5)	7(1)
H(4")	1108(5)	290(2)	809(2)	3(1)
H(5"1)	759(7)	248(3)	612(4)	6(1)
H(5"2)	693(8)	342(3)	594(4)	6(1)
H(5")0	1095(6)	346(2)	552(3)	5(1)

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EXPERIMENTAL

Melting points (uncorrected) were determined with a Büchi-Tottoli instrument. UV spectra were recorded on a Philips PU8740 UV/VIS spectrophotometer. Optical rotations were measured with a JASCO DIP-360 automatic polarimeter at 20 °C. Liquid secondary ion mass spectra (LSIMS) were obtained using a Kratos Concept 1H mass spectrometer (Manchester, U.K.). Column chromatography was performed on silica gel (0.06-0.20 mm), TLC was carried out on Kieselgel 60 F (Merck) with detection by UV light.

Table 4. Calculated and X-ray torsion angles.

Compound	5a calculated[1]	5b calculated	5c calculated	5c X-ray
Torsion angle	Ado	Cyd	Urd	
H1'-C1'-C2'-H2'	137	132	132	118.4
H2'-C2'-C3'-H3'	58	56	56	25.9
H3'-C3'-C4'-H4'	-135	-142	-143	-165.3
H4'-C4'-C5'-H5'a	-57	-54	-55	-173.5
H4'-C4'-C5'-H5'b	61	61	64	68.9
C4'-O4'-C1'-C2'	-25	-23	-23	-22.0
O4'-C1'-C2'-C3'	2	-1	-1	-0.4
C1'-C2'-C3'-C4'	19	22	22	20.8
C2'-C3'-C4'-O4'	-34	-36	-36	-34.3
C3'-C4'-O4'-C1'	39	39	39	35.4
C3'-C4'-C5'-O5'[2]	64	64	65	-177.0
P[3]	60	55	55	54.6
Torsion angle	Rib	Rib	Rib	
H1"-C1"-C2"-H2"	75	75	75	84.1
H2"-C2"-C3"-H3"	48	48	47	42.3
H3"-C3"-C4"-H4"	-152	-148	-150	-152.0
H4"-C4"-C5"-H5"a	-50	-52	-52	66.9
H4"-C4"-C5"-H5"b	52	51	51	-177.7
C4"-O4"-C1"-C2"	24	25	25	21.9
O4"-C1"-C2"-C3"	-39	-40	-39	-36.1
C1"-C2"-C3"-C4"	38	37	38	35.8
C2"-C3"-C4"-O4"	-26	-25	-25	-24.5
C3"-C4"-O4"-C1"	2	0	1	2.0
C3"-C4"-C5"-O5"	59	59	58	-177.9
P	343	340	342	344.4

1. H-C-C-H torsion angles are computed from NMR coupling constants using the Karplus equation. Other torsion angles are derived from the H-C-C-H torsion angles using a molecular modelling package.
2. Exocyclic CH_2OH torision angle (ref. 19)
3. Pseudorotation phase angle.

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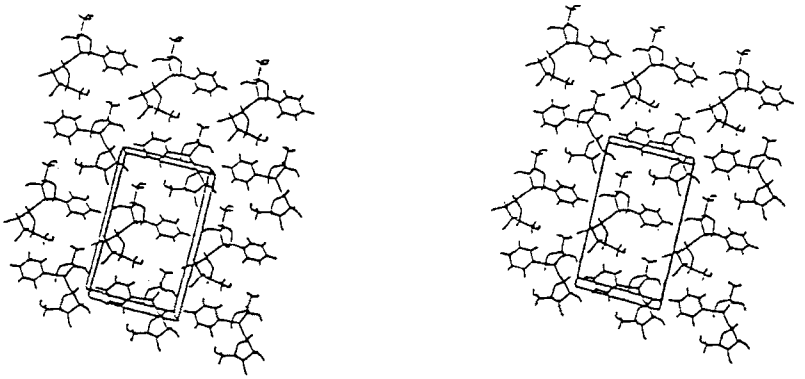

Figure 2. Stereo plot of crystal packing of Urd-Rib with unit cell.

^{1}H NMR spectra were recorded using a Gemini 200 NMR (K.U.Leuven) and a Bruker AM 360 spectrometer at 20 °C (U. Ghent). Chemical shifts were measured relative to solvent signals. The signals were assigned by the double resonance techniques. The COSY and NOESY experiments were performed on the Bruker AM 360 Apparatus. The COSY45 spectra were recorded in the absolute value mode using a 90° (1H)-t_1-45°(1H)-t_2 sequence. A 0.5 x 1 K data matrix was obtained using 32 scans without zero filling. Resolution enhancements in $\omega 1$ and $\omega 2$ were obtained by a $\Pi/2$ shifted sine-bell function in both t_1 and t_2. The 90° (1H) pulse was 5.4 μs, with a delay of 1.5 s. For the NOESY experiment a 90° (1H)-t_1-90°(1H)-τm-90°(1H)-t_2 sequence was used (the same circumstances as for COSY45 τm = 80 ms and $\Delta\tau m$ = 10%).

The spectra of 2'-*O*-ribofuranosyl-cytidine were recorded at the Complex Carbohydrate Research Center (CCRC), The University of Georgia, Athens, USA, on a BRUKER AM 500 and AM 250 apparatus, equipped with ASPECT 3000 computers at 25°C. The proton resonances (see Table 1) were assigned from a DQF-COSY, acquired with 4096 x 512 data points for a spectral width of 2994 Hz, zero-filled in F1 direction and multiplied by a 60 degree shifted sine-bell function in both dimensions before FT. The ^{1}H 90° pulse is 7.8 μs. The ^{13}C resonances (given in Experimental) were assigned from a HETCOR experiment acquired with ^{13}C detection (125 Hz with 4096 x 512 data points and a 17.857 Hz spectral width). The data matrix was multiplied by an exponential function (1 Hz line broadening) in F2, multiplied by a gaussian function and zerofilled in F1 before FT. The chemical shifts for this compound in Table 1 are expressed in ppm from internal acetone (2.225 ppm for ^{1}H and 31.55 ppm for ^{13}C). For the HETCOR experiment the 1H 90° pulse was 5.3 μs and the ^{13}C 90° pulse was 19 μs.

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Crystals for X-ray analysis were obtained from a saturated aqueous solution of **5c** by slowly evaporating the solvent at 20 °C. The X-ray data were measured on CAD-4 diffractometer (MoKα-radiation, the Θ/2Θ scan technique). The space group of **5c** crystals is $p2_1$, z=2. The cell dimensions are a = 4.986(1) Å, b= 16.256(2) Å, c = 9.981(1) Å, α = γ = 90 deg., β = 102.19 deg., V = 790.7(0.4) $Å^3$. The structure was solved by a direct method and refined by the full-matrix least squares with anisotropic approximation for nonhydrogen atoms. The hydrogen atom coordinates were determined from the difference of Fourier syntheses and refined using the isotropic temperature factors. The final value of R factors was 2.0% for 1211 independent reflections.

***N*^{6}-Benzoyl-9-[3,5-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-2-*O*-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl]adenine (3a).** To a cool solution (0 °C) of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose (1.26 g, 2.5 mmol) in 1,2-dichloroethane (25 mL) tin tetrachloride (0.35 mL, 3 mmol) was added under nitrogen and the solution was kept at 0 °C for 10 min. After addition of nucleoside **1a** (1.23 g, 2 mmol) the resulting solution was kept at 0 °C for 7 h. The 10 % aqueous solution of sodium bicarbonate (10 mL) was added and the suspension was stirred at 0 °C for 20 min. The suspension was filtered through Hyflo Super Cel, the organic layer was separated, washed with water (20 mL), dried and concentrated to dryness. The residue was purified by column chromatography on silica gel (50 g). The column was washed with methylene chloride (500 mL) and then eluted with 0.7 % methanol in methylene chloride to give **3a** as a foam. Yield 1.5-1.66 g (71-77 %). LSIMS $[M+H]^+$ 1058; exact mass ($C_{55}H_{64}N_5O_{13}Si_2$) found 1058.4006, calcd 1058.4039. ^1H NMR ($CDCl_3$) 9.02 brs (1H, NH), 8.73 s (1H, H-8), 8.13 (s, 1H, H-2), 8.03-7.87 m (8H, Bz), 7.61-7.28 m (12H, Bz), 6.09 s (1H, H-1', Ado), 5.97 dd (1H, $J_{3',2'}$ = 4.8 Hz, $J_{3',4'}$ = 6.3 Hz, H-3', Rib), 5.89 d (1H, H-2', Rib), 5.82 s (1H, H-1', Rib), 5.00-4.65 m (5H, H-2',3', Ado, H-4',5'a,5'b, Rib), 4.25-3.97 m (3H, H-4',5'a,5'b, Ado), 1.13-0.91 m (28H, iPr). ^{13}C NMR ($CDCl_3$) 166.01, 165.37, 164.97 and 164.43 (C=O), 152.70 (C-2), 150.76 (C-6), 149.35 (C-4), 141.80 (C-8), 133.41, 133.16, 132.69, 129.71, 129.64, 129.10, 128.83, 128.34 and 127.78 (Bz), 123.40 (C-5), 105.65 (C-1', Rib), 88.81 (C-1', Ado), 75.51 (C-2', Rib), 72.53 (C-3', Rib), 69.84 (C-3', Ado), 65.27 (C-5', Rib), 59.70 (C-5', Ado), 17.26, 17.04, 16.87, 16.77, 13.31, 12.98, 12.74 and 12.59 (iPr).

***N*^{4}-Benzoyl-1-[3,5-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-2-*O*-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl]cytosine (3b).** Following the procedure for preparation of **3a**, condensation of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose (1.77 g, 3.5 mmol) in the presence of tin tetrachloride (0.46 mL, 3.9 mmol) with **1b** (1.46 g, 3 mmol) in 1,2-dichloroethane (30 mL) at 0 °C for 2 h gave **3b** as a foam. Yield 2.23 g (80%). LSIMS $[M+H]^+$ 1034, $[M+Na]^+$ 1056; exact mass

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($C_{54}H_{64}N_3O_{14}Si_2$) found 1034.3929, calcd 1034.3926. ^{1}H NMR ($CDCl_3$) 8.77 brs (1H, NH), 8.32 d (1H, $J_{6,5}$ = 7.6 Hz, H-6), 8.04-7.84 m (8H, Bz), 7.60-7.24 m (13H, H-5, Bz), 5.98 s (1H, H-1', Cyd), 5.91 dd (1H, $J_{3',2'}$ = 4.7 Hz, $J_{3',4'}$ = 6.5 Hz, H-3', Rib), 5.83 d (1H, H-2', Rib), 5.29 s (1H, H-1', Rib), 4.88-3.91 m (8H, H-2',3',4',5'a,5'b, Cyd, H-4',5'a,5'b, Rib), 1.14-0.92 m (28H, iPr). ^{13}C NMR ($CDCl_3$) 166.09 (C-4), 165.28, 165.05 and 162.40 (C=O), 155.02 (C-2), 144.36 (C-6), 133.31, 133.18, 132.80, 129.74, 129.23, 128.98, 128.37, 128.21 and 127.53 (Bz), 105.48 (C-1', Rib), 96.02 (C-5), 90.14 (C-1', Cyd), 81.81 (C-4', Cyd), 79.07 (C-4', Rib), 78.51 (C-2', Cyd), 75.63 (C-2', Rib), 73.10 (C-3', Rib), 68.71 (C-3', Cyd), 65.51 and 59.32 (C-5'), 17.41, 17.28, 17.06, 16.91, 16.77, 13.31, 13.02, 12.85 and 12.50 (iPr).

1-[3,5-(1,1,3,3-Tetraisopropyldisiloxane-1,3-diyl)-2-*O*-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl]uracil (3c). Following the procedure for preparation of **3a**, condensation of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose (1.77 g, 3.5 mmol) in the presence of tin tetrachloride (0.46 mL, 3.9 mmol) with **1c** (1.77 g, 3 mmol) in 1,2-dichloroethane (30 mL) at 0 °C for 2 h gave **3c** as a foam. Yield 2.36 g (76 %). LSIMS $[M+Na]^+$ 953; exact mass ($C_{47}H_{58}N_2O_{14}Si_2$) found 953.3383, calcd 953.3324. ^{1}H NMR ($CDCl_3$) 9.37 brs (1H, NH), 8.05-7.85 m (6H, Bz), 7.7.81 (1H, $J_{6,5}$ = 8.1 Hz, H-6), 7.56-7.26 (9H, Bz), 5.90 dd (1H, $J_{3',2'}$ = 4.8 Hz, $J_{3',4'}$ = 6.1 Hz, H-3', Rib), 5.82 d (1H, H-2', Rib), 5.80 s (1H, H-1', Urd), 5.65 d (1H, H-5), 5.28 s (1H, H-1', Rib), 4.81-3.91 m (8H, H-2',3',4',5'a,5'b, Urd, H-4',5'a,5'b, Rib), 1.12-0.91 m (28H, iPr). ^{13}C NMR ($CDCl_3$) 166.01, 165.22 and 164.95 (C=O), 163.51 (C-4), 149.68 (C-2), 139.41 (C-6), 133.31, 133.21, 133.00, 132.83, 129.64, 129.10, 128.87, 128.32 and 128.21 (Bz), 105.44 (C-1', Rib), 101.45 (C-5), 89.25 (C-1', Cyd), 81.52 (C-4', Urd), 79.33 (C-4', Rib), 78.47 (C-2', Urd), 75.47 (C-2', Rib), 72.96 (C-3', Rib), 68.71 (C-3', Urd), 65.60 (C-5', Urd), 17.22, 17.12, 17.01, 16.77, 16.67, 13.26, 12.91, 12.75 and 12.42 (iPr).

1-[3,5-(1,1,3,3-Tetraisopropyldisiloxane-1,3-diyl)-2-*O*-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl]thymine (3d). Following the procedure for preparation of **3a**, condensation of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose (1.2 g, 2.4 mmol) in the presence of tin tetrachloride (0.35 mL, 2.9 mmol) with **1d** (1.0 g, 2 mmol) in 1,2-dichloroethane (10 mol) at 0 °C for 2 h gave **3d** as a foam. Yield 1.4 g (74%). LSIMS $[M+Na]^+$ 967; exact mass ($C_{48}H_{60}N_2NaO_{14}Si_2$) found 967.3462, calcd 967.3481. ^{1}H NMR ($CDCl_3$) (360 MHz) : 8.21 brs (1H, NH), 8.00-7.83 m (6H, Bz), 7.55-7.25 (10H, Bz, H-6), 5.85 (1H, $J_{3',2'}$ = 5.0 Hz, $J_{3',4'}$ = 6.5 Hz, H-3', Rib), 5.78 d (1H, H-2', Rib), 5.76 s (1H, H-1', Thd), 5.75 s (1H, H-1', Rib), 4.77-4.69 m (3H, H-3',4', Thd; H-4', Rib), 4.39 d (1H, $J_{2',3'}$ = 4.3 Hz, H-2', Thd), 4.30 dd (1H, $J_{5'a,4'}$ = 4.4 Hz, $J_{5'a,5'b}$ = -9.5 Hz, H-5'a, Thd), 4.18 (1H, $J_{5'a,5'b}$ = -13.4 Hz, H-5'a, Rib), 4.04 dd

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(1H, $J_{5'b,4'}$ = 2.0 Hz, H-5'b, Thd), 3.92 dd (1H, $J_{5',4'}$ = 2.6 Hz, H-5'b, Rib), 1.86 d (3H, $J_{5,6}$ = 1.2 Hz), 1.07-0.92 m (28H, iPr). ^{13}C NMR ($CDCl_3$) : 166.11 and 165.32 (C=O), 165.01 (C-), 149.55 (C-2), 135.27 (C-6), 133.39, 133.30, 132.96, 129.72, 129.18, 128.94, 128.41, 128.29 and 128.25 (Bz), 110.09 (C-5), 105.51 (C-1', Rib), 89.64 (C-1', Thd), 81.48 (C-4', Thd), 79.38 (C-4', Rib), 78.52 (C-2', Thd), 75.53 (C-2', Rib), 73.05 (C-3', Rib), 69.02 (C-3', Thd), 65.77 (C-5', Rib), 59.25 (C-5', Thd), 17.41, 17.33, 17.22, 17.13, 17.01, 16.88, 16.77, 13.42, 12.86 and 12.68 (iPr), 12.57 (Me-5).

***N*^{2}-*iso*-Butyryl-9-[3,5-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-2-*O*-(2,3-tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl]guanine (3e).** Following the procedure for preparation of **3a**, condensation of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose (1.31 g, 2.6 mmol) in the presence of tin tetrachloride (0.34 mL, 2.8 mmol) with **1e** (1.19 g, 2.6 mmol) in 1,2-dichloroethane (20 mL) at 0 °C for 16 h gave **3e** as a foam. Yield 1.7 g (82%). LSIMS $[M+Na]^+$ 1040, $[M+Na]^+$ 1062; exact mass ($C_{52}H_{66}N_5O_{14}Si_2$) found 1040.4108, calcd 1040.4144. ^1H NMR ($CDCl_3$) : 12.19 brs (1H, NH), 9.81 brs (1H, NH), 8.08 s (1H, H-8), 8.00-7.82 m (6H, Bz), 7.55-7.26 (9H, Bz), 6.10 (1H, $J_{3',2'}$ = 5.1 Hz, $J_{3',4'}$ = 5.8 Hz, H-3', Rib), 5.86 d (1H, $J_{2',1'}$ = 0.9 Hz, H-2', Rib), 5.79 s (1H, H-1', Rib), 5.72 s (1H, H-1', Guo), 4.87-3.91 m (8H, H-2',3',4',5'a,5'b, Guo; H-4',5'a,5'b, Rib), 2.86 sep (1H, J = 6.8 Hz, CH, iBu), 1.32 d (3H, Me, iBu), 1.22 d (3H, Me iBu), 1.07-0.92 m (28H, iPr). ^{13}C NMR ($CDCl_3$) : 179.42, 167.87, 165.34 and 165.00 (C=O), 155.42 (C-6), 148.27 (C-2), 147.09 (C-4), 135.91 (C-8), 134.01, 133.57, 129.71, 128.95, 128.83, 128.66 and 128.45 (Bz), 121.60 (C-5), 105.46 (C-1', Rib), 87.32 (C-1', Guo), 81.17 (C-4', Guo), 79.38 (C-4', Rib), 78.75 (C-2', Guo), 75.81 (C-2', Rib), 73.29 (C-3', Rib), 69.31 (C-3', Guo), 65.65 (C-5', Rib), 59.41 (C-5', Guo), 36.10 (CH, iBu), 19.21 (Me, iBu), 18.92 (Me, iBu), 17.48, 17.31, 17.13, 16.69, 16.80, 16.71, 13.32, 13.06, 12.82 and 12.53 (iPr).

***N*^{6}-Benzoyl-9-[2-*O*-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl)adenine (4a).** Nucleoside **3a** (1.06 g, 1 mmol) was dissolved in 0.5 M tetrabutylammonium fluoride trihydrate in tetrahydrofuran (5 mL), kept for 15 min at 20 °C and the solution concentrated to dryness. A solution of the residue in chloroform (10 mL) was concentrated and applied to a column of silica gel (30 g). The column was washed with methylene chloride (300 mL) and then eluted with 2% methanol in methylene chloride to give **4a** as a foam. Yield 0.74 g (91%). LSIMS $[M+H]^+$ 816, $[M+Na]^+$ 838; exact mass ($C_{43}H_{38}N_5O_{12}$) found 816.2496, calcd 816.2517. ^1H NMR ($CDCl_3$) 9.52 brs (1H, NH), 8.78 s (1H, H-8), 8.39 s (1H, H-2), 8.03-7.81 m (8H, Bz), 7.56-7.25 m (12H, Bz), 6.21 d (1H, $J_{1',2'}$ = 7.0, H-1', Ado), 5.72 m (2H, H-2',3', Rib), 5.30 s (1H, H-1', Rib), 4.72-3.63 m (8H, H-2',3',4',5'a,5'b, Ado; H-4',5'a,5'b, Rib). ^{13}C NMR ($CDCl_3$) 165.71, 165.21 and 164.66 (C=O), 151.96 (C-2), 150.26 (C-6), 150.11 (C-4), 143.85 (C-

8), 133.47, 133.36, 133.16, 132.54, 129.51, 129.41, 128.94, 128.54 and 127.82 (Bz), 123.80 (C-5), 106.19 (C-1', Rib), 88.86 (C-1', Ado), 86.99 (C-4', Ado), 80.48 (C-4', Rib), 79.53 (C-2', Ado), 75.61 (C-2', Rib), 72.18 (C-3', Rib), 71.06 (C-3', Ado), 64.12 (C-5', Rib), 62.73 (C-5', Ado).

N^4-Benzoyl-1-[2-*O*-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl)cytosine (4b). Following the procedure for preparation of **4a**, analogous desilylation of **3b** yielded **4b** as a foam (95%). LSIMS $[M+H]^+$ 792; exact mass ($C_{42}H_{38}N_3O_{13}$) found 792.2403, calcd 792.2404. ^1H NMR ($CDCl_3$) 9.18 brs (1H, NH), 8.34 d (1H, $J_{6,5}$ = 7.4, H-6), 8.01-7.82 m (8H, Bz), 7.51-7.23 m (13H, H-5, Bz), 5.97 d (1H, $J_{1',2'}$ = 2.2, H-1', Cyd), 5.89 dd (1H, $J_{3',2'}$ = 5.2, $J_{3',4'}$ = 5.5, H-3', Rib), 5.83 d (1H, H-2', Rib), 5.75 s (1H, H-1', Rib), 4.80-3.81 m (8H, H-2',3',4',5'a, 5'b, Cyd; H-4',5'a,5'b, Rib). ^{13}C NMR ($CDCl_3$): 166.57 (C-4), 166.05, 165.37 and 152.77 (C=O), 155.31 (C-2), 147.17 (C-6), 133.46, 133.35, 133.14, 132.95, 129.67, 129.42, 128.76, 128.35 and 127.71 (Bz), 106.66 (C-1', Rib), 96.87 (C-5), 92.38 (C-1', Cyd), 84.87 (C-4', Cyd), 80.67 (C-4', Rib), 79.51 (C-2', Cyd), 75.87 (C-2', Rib), 72.57 (C-3', Rib), 68.34 (C-3', Cyd), 64.82 (C-5', Rib), 60.56 (C-5', Cyd).

1-[2-*O*-(2,3,5-Tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl)uracil (4c). Following the procedure for preparation of **4a**, desilylation of **3c** yielded **4c** as a foam (92%). LSIMS $[M+H]^+$ 689, exact mass ($C_{35}H_{33}N_2O_{13}$) found 689.1955, calcd 689.1982. ^1H NMR ($CDCl_3$) 9.65 brs (1H, NH), 8.03-7.83 m (6H, Bz), 7.66 d (1H, $J_{6,5}$ = 8.0, H-6), 7.52-7.25 m (9H, Bz), 5.82 m (3H, H-1', Urd, H-2',3', Rib), 5.62 d (1H, H-5), 5.55 s (1H, H-1', Rib), 4.73-3.65 m (8H, H-2',3',4',5'a,5'b, Urd; H-4',5'a,5'b, Rib). ^{13}C NMR ($CDCl_3$) 166.12 and 165.46 (C=O), 163.78 (C-4), 150.41 (C-2), 142.54 (C-6), 133.51, 133.47, 133.28, 129.69, 129.34, 128.68 and 128.42 (Bz), 106.82 (C-1', Rib), 102.08 (C-5), 91.10 (C-1', Cyd), 84.51 (C-4', Urd), 80.65 (C-4', Rib), 79.75 (C-2', Urd), 75.77 (C-2', Rib), 72.40 (C-3', Rib), 69.08 (C-3', Urd), 64.65 (C-5', Rib), 61.14 (C-5', Urd).

1-[2-*O*-(2,3,5-Tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl]thymine (4d). Following the procedure for preparation of **4a**, desilyation of **3d** yielded **4d** as a foam (87%). LSIMS $[M+H]^+$ 703; exact mass ($C_{36}H_{35}N_2O_{13}$) found 703.2152, calcd 703.2139. ^1H NMR ($CDCl_3$-CD_3OD) (360 MHz) : 7.98-7.81 m (6H, Bz), 7.42 q (1H, $J_{6,5}$ = 1.2 Hz, H-6), 7.49-7.25 m (9H, Bz), 5.76 d (1H, $J_{1',2'}$ = 4.2 Hz, H-1', Rib), 5.74 dd (1H, $J_{3',2'}$ = 5.1 Hz, $J_{3',4'}$ = 6.2 Hz, H-3', Rib), 5.69 dd (1H, $J_{2',1'}$ = 1.2 Hz, H-2', Rib), 6.44 d (1H, H-1', Rib), 4.66 ddd (1H, $J_{4',3'}$ = 5.6 Hz, $J_{4',5'a}$ = 4.5 Hz, $J_{4',4'b}$ = 5.3 Hz, H-4', Thd), 4.57 dd (1H, $J_{5'a,5'b}$ = -11.8 Hz, H-5'a, Thd), 4.52 dd (1H, $J_{2',3'}$ = 5.2 Hz, H-2', Thd), 4.44 dd (1H, H-5'b, Thd), 4.31 dd (1H, H-3', Thd), 3.89 ddd (1H, $J_{4',5'a}$ = 2.3 Hz, $J_{4',5'b}$ = 2.5 Hz, H-4', Rib), 3.79 dd (1H, $J_{5'a,5'b}$ = -12.5 Hz, H-5'a,

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Rib), 3.66 dd (1H, H-5'b, Rib), 1.76 d (1H, Me-5). ^{13}C NMR ($CDCl_3$-CD_3OD) : 166.15 and 165.48 (C=O), 164.33 (C-4), 150.55 (C-2), 137.74 (C-6), 133.62, 133.47, 133.21, 129.62, 129.54, 129.18, 128.55, 128.48, 128.38, 128.31 and 128.28 (Bz), 110.48 (C-5), 106.31 (C-1', Rib), 89.92 (C-1', Thd), 84.36 (C-4', Thd), 79.31 (C-4', Rib), 77.32 (C-2', Thd), 75.57 (C-2', Rib), 72.36 (C-3', Rib), 68.89 (C-3', Thd), 64.69 (C-5', Rib), 60.79 (C-5', Thd), 11.96 (Me-5).

***N*^{2}-*iso*-Butyryl-9-[2-*O*-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-β-D-ribofuranosyl]guanine (4e).** Following the procedure for preparation of **4a**, desilyation of **3e** yielded **4e** as a foam (84%). LSIMS $[M+H]^+$ 798; exact mass ($C_{40}H_{40}N_5O_{13}$) found 798.2585, calcd 798.2622. ^1H NMR $CDCl_3$) : 12.34 brs (1H, NH), 9.95 brs (1H, NH), 8.81 s (1H, H-8), 7.97-7.82 m (6H, Bz), 7.56-7.26 m (9H, Bz), 6.07 (1H, $J_{3',2'}$ = 5.1 Hz, $J_{3',4'}$ = 5.9 Hz, H-3', Rib), 5.87-5.83 m (3H, H-1',2', Rib; H-1', Guo), 4.77-4.09 m (8H, H-2',3',4',5'a,5'b, Guo; H-4',5'a,5'b, Rib), 2.82 sep (1H, J = 6.8 Hz, CH, iBu), 1.28 d (3H, Me, iBu), 1.19 d (3H, Me, iBu). ^{13}C NMR ($CDCl_3$) : 179.73, 167.77 and 165.27 (C=O), 155.95 (C-6), 148.03 (C-2), 147.48 (C-4), 138.98 (C-8), 133.93, 133.48, 129.73, 129.69, 128.99, 128.83, 128.64, 128.45 and 128.39 (Bz), 120.50 (C-5), 105.48 (C-1', Rib), 87.97 (C-1', Guo), 83.67 (C-4', Guo), 79.25 (C-4', Rib), 77.32 (C-2', Guo), 75.82 (C-2', Rib), 73.07 (C-3', Rib), 68.79 (C-3', Guo), 65.57 (C-5', Rib), 59.83 (C-5', Guo), 36.05 (CH, iBu), 19.13 (Me, iBu), 18.85 (Me, iBu).

9-(2-*O*-β-D-Ribofuranosyl-β-D-ribofuranosyl)adenine (5a). A solution of nucleoside **4a** (408 mg, 0.5 mmol) in 5 M ammonia in methanol (15 mL) was kept for 5 days at 20 °C and then concentrated in vacuo to dryness. The residue was partitioned between methylene chloride (10 mL) and water (20 mL), and the water layer was washed with methylene chloride (2 x 10 mL). The aqueous layer was concentrated to dryness, the residue was dissolved in 1 ml of water, methanol (7 mL) was added and the mixture was kept at 0 °C for 16 h. The formed crystals were filtered, washed with methanol and dried to yield **5a** (190 mg, 91%). Mp 212-214 °C (softening at 162-164 °C). $[\alpha]_D$-97° (*c* 0.76, DMSO). UV (pH 7 and 13) : λ_{max} 261 nm (ε 14200); (pH 1) : λ_{max} 261 nm (ε 13700). LSIMS $[M+H]^+$ 400; exact mass ($C_{15}H_{22}N_5O_8$) found 400.1465, calcd 400.1468. ^1H NMR (see Table 1). ^{13}C NMR (D_2O): 156.14 (C-6), 153.06 (C-2), 149.74 (C-4), 141.08 (C-8), 119.42 (C-5), 106.42 (C-1', Rib), 87.44 (C-1', Ado), 86.84 (C-4', Ado), 83.11 (C-4', Rib), 78.64 (C-2', Ado), 74.75 (C-2', Rib), 71.31 (C-3', Rib), 69.43 (C-3', Ado), 63.16 (C-5', Rib), 61.88 (C-5', Ado).

Anal. Calcd for $C_{15}H_{21}N_5O_8$ x H_2O : C 43.17; H 5.55; N 16.78. Found : C 42.90; H 5.63; N 16.43.

1-(2-*O*-β-D-Ribofuranosyl-β-D-ribofuranosyl)cytosine (5b). Following the procedure for preparation of **5a**, debenzoylation of **4b** after evaporation with methanol

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yielded **5b** as a hygroscopic foam (178 mg, 95%). $[\alpha]_D$-29° (*c* 0.53, water). UV (pH 7 and 13) : λ_{max} 271 nm (ε 8200); (pH 1) : λ_{max} 279 nm (ε 12200). LSIMS $[M+H]^+$ 376; exact mass ($C_{14}H_{22}N_3O_9$) found 376.1338, calcd 376.1356. ^1H NMR (see Table 1). ^{13}C NMR (D_2O) 167.42 (C-4), 158.89 (C-2), 143.11 (C-6), 107.80 (C-1', Rib), 98.01 (C-5), 89.56 (C-1', Cyd), 85.91 (C-4', Cyd), 84.13 (C-4', Rib), 79.78 (C-2', Cyd), 75.68 (C-2', Rib), 72.08 (C-3', Rib), 69.74 (C-3', Cyd), 64.35 (C-5', Rib), 62.18 (C-5', Cyd).

Anal. Calcd for $C_{14}H_{21}N_3O_9$ x $2CH_3OH$: C 43.73; H 6.65; N 9.56. Found : C 43.84; H 6.23; N 9.73.

1-(2-*O*-β-D-Ribofuranosyl-β-D-ribofuranosyl)uracil (5c). Following the procedure for preparation of **5a**, debenzoylation of **4c** yielded **5c** after crystallization from water (150 mg, 80%). Mp 224-225 °C. $[\alpha]_D$-36° (*c* 0.68, DMSO). UV (pH 1 and 7) : λ_{max} 262 nm (ε 9400); (pH 13) : λ_{max} 262 nm (ε 6900). LSIMS $[M+H]^+$ 377; exact mass ($C_{15}H_{22}N_5O_8$) found 377.2801, calcd 377.1196. ^1H NMR (see Table 1). ^{13}C NMR (D_2O) 166.66 (C-4), 152.17 (C-2), 142.55 (C-6), 107.28 (C-1', Rib), 103.06 (C-5), 88.47 (C-1', Urd), 85.11 (C-4', Urd), 83.35 (C-4', Rib), 78.93 (C-2', Urd), 74.85 (C-2', Rib), 71.14 (C-3', Rib), 68.87 (C-3', Urd), 63.34 (C-5', Rib), 61.17 (C-5', Urd).

Anal. Calcd for $C_{14}H_{20}N_3O_{10}$: C 44.68; H 5.36; N 7.44. Found : C 44.51; H 5.41; N 7.47.

1-(2-*O*-β-D-Ribofuranosyl-β-D-ribofuranosyl)thymine (5d). Following the procedure for preparation of **5a**, debenzoylation of **4d** yielded **5d** after crystallization from aqueous ethanol (148 mg, 75%). Mp 236-237 °C. $[\alpha]_D$-52° (*c* 0.82, water). UV (pH 1 and 7) : λ_{max} 269 nm (ε 9400); (pH 13) : λ_{max} 262 nm (ε 7100). LSIMS $[M+H]^+$ 391; exact mass ($C_{15}H_{23}N_2O_{10}$) found 391.1362, calcd 391.1352. ^1H NMR (see Table 1). ^{13}C NMR (D_2O) : 167.28 (C-4), 152.71 (C-2), 138.49 (C-6), 112.82 (C-5), 107.71 (C-1', Rib), 88.50 (C-1', Thd), 85.60 (C-4', Thd), 83.88 (C-4', Rib), 79.17 (C-2', Thd), 75.32 (C-2', Rib), 71.74 (C-3', Rib), 69.32 (C-3', Thd), 64.03 (C-5', Rib), 61.71 (C-5', Thd), 12.47 (Me-5).

Anal. Calcd $C_{15}H_{22}N_2O_{10}$: C 46.14, H 5.68, N 7.18. Found : C 46.35, H 5.49, N 7.40.

9-(2-*O*-β-D-Ribofuranosyl-β-D-ribofuranosyl)guanine (5e). Following the procedure for preparation of **5a**, debenzoylation of **4e** yielded **5e** after crystallization from ethanol (158 mg, 76%). Mp 215-216 °C. $[\alpha]_D$-75° (*c* 0.92, water). UV (pH 1) : λ_{max} 257 nm (ε 10.800); (pH 7) : λ_{max} 254 nm (ε 1200); (pH 13) : λ_{max} 263 nm (ε 10000). LSIMS $[M+H]^+$ 416; exact mass ($C_{15}H_{22}N_5O_9$) found 416.1413, calcd 416.1417. ^1H NMR (see table). ^{13}C NMR (D2O) : 159.89 (C-6), 139.28 (C-8), 128.37 (C-8), 117.67 (C-5), 107.18 (C-1', Rib), 87.52 (C-1', Guo), 87.03 (C-4', Guo), 83.80 (C-4', Rib),

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78.98 (C-2', Guo), 75.37 (C-2', Rib), 72.06 (C-3', Rib), 69.96 (C-3', Guo), 64.02 (C-5', Rib), 62.41 (C-5', Guo).

Anal. Calcd $C_{15}H_{21}N_5O_9$: C 43.36, H 5.10, N 16.87. Found : C 43.60, H 5.33, N 16.59.

Isopropyl 2,3,5-tri-*O*-benzoyl-β-D-ribofuranoside (6b). ^1H NMR ($CDCl_3$) 8.06-7.88 m (6H, Bz), 7.62-7.25 m (9H, Bz), 5.88 dd (1H, $J_{3,2}$ = 4.8, $J_{3,4}$ = 6.4, H-3), 5.64 d (1H, H-2), 5.37 s (1H, H-1), 4.75-4.51 m (3H, H-4,5a,5b), 4.00 sep (1H, JCH, Me 6.2, CH), 1.21 d (3H, Me), 1.18 d (3H, Me). ^{13}C NMR ($CDCl_3$) 166.13 and 165.30 (C=O), 133.37, 133.27, 133.02, 129.71, 129.29, 128.98, 128.40 and 128.26 (Bz), 103.72 (C-1), 78.47 (C-4), 76.02 (C-2), 72.79 (C-3), 70.57 (CH), 65.34 (C-5), 23.26 (Me), 21.47 (Me).

Isopropyl β-D-ribofuranoside (6b). Following the procedure for preparation of **5a**, debenzoylation of isopropyl 2,3,5-tri-*O*-benzoyl-β-D-ribofuranoside (1 mmol) with 5 M ammonia in methanol (10 mL) for 3 days at 20 °C gave **5** as an oil (83%). ^1H NMR (see Table 1). ^3C NMR (D_2O) 105.30 (C-1), 83.06 (C-4), 75.00 (C-2), 71.54 (CH), 71.34 (C-3), 63.42 (C-5), 22.81 (Me), 21.09 (Me). LSIMS $[M+H]^+$ 193, $[M+Na]^+$ 215; exact mass ($C_8H_{17}O_5$) found 193.1067, calcd 193.1067.

ACKNOWLEDGEMENT

Financial support from INTAS (project 93-1500) and NATO (grant HTECH.CRG 940362) and Russian Fund of Fundamental Sciences (project 93-04-07959 and 95-03-08347) is gratefully acknowledged. We thank Dr. Herman Van Halbeek and Dr. Guiseppe Impallomeni for recording the spectra of 2'-*O*-ribofuranosylcytidine at CCRC, University of Georgia, Athens, Georgia, USA, supported by NIH grant P-41 RR05351.

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