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Synthesis of homo-N-nucleosides, a series of C1' branched-chain nucleosides.

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Abstract : Homo-N-desoxynucleosides were synthesized starting from 2-deoxy-D-ribose using a one step epoxidation-ring closure appraoch. The configuration of the nucleosides were proven using NMR and X-ray analysis.

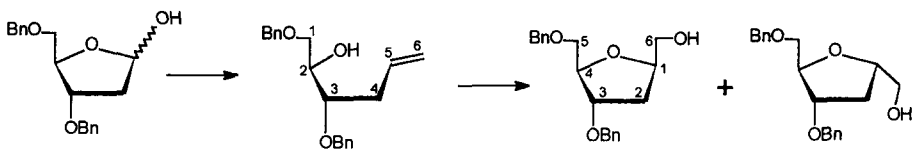
INTRODUCTION

C-Glycosidic nucleosides are a well known class of modified nucleosides and many examples exist in nature.[1] As for example, showdomycin[2] is a biological interesting nucleoside analogue with a *C*-glycosidic linkage. Normal nucleosides have a N-glycosidic linkage and this linkage contributes to the typical conformational preferences of natural nucleosides. When a methylene group is inserted between the N1/N9 of the heterocyclic bases and C1' of the pentofuranosyl ring, the anomeric effect is lost. Moreover, the heterocyclic base moiety occupies a more flexible position. When considering oligonucleotides composed of these modified nucleosides, the distance between backbone and base moieties is increased, lowering electrostatic repulsion. Because of the flexibility of thus formed nucleoside bases, they might still be able to base pair with a natural DNA (or RNA) complement. Therefore, we became interested in a synthetic scheme leading to homo-N-nucleosides. A recent paper[3] describes the insertion of a methylene unit between N9 of guanine and C1' of pyrrolidine, while the introduction of a methylene unit between C1' of pentofuranose and C6 of pyrimidine analogue has been described before by J. Secrist.[4] However, nucleosides with a methylene bridge between C1' and N9 / N1 of dA, dG, dC and T are hitherto unknown.

RESULTS AND DISCUSSIONS

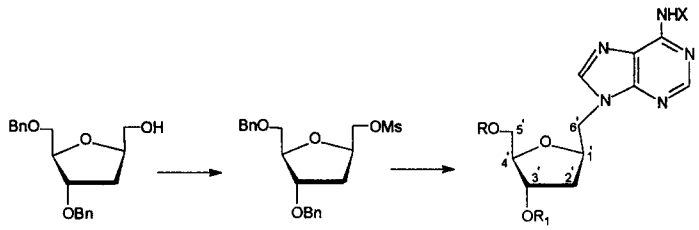
Compound **1** was prepared as described in literature[5] starting from 2-deoxy-D-ribose in 65% yield. When the unreacted intermediates were reused the yield of **1** can be increased to 90%. The reaction of **1** with methyltriphenyl phosphonium bromide in the presence of butyl lithium in toluene yielded olefine[6] **2** in 70% yield. Epoxidation[7] of **2** in the presence of meta-choloroperbenzoic acid (mcpba) in dichloromethane at room temperature for 48 h gave a mixture of *C*-glycosides[8] **3** and **4** in a combined yield of 84%. The epoxide thus formed was instantaneously opend by neighbouring group participation with the aid of acid catalyst. Both of the isomers were separated by silica gel column chromatography to afford **3** (46.2%) and **4** (37.5%) in the pure form. The reaction of **2** with mcpba in dichloromethane at -20 °C became extremely sluggish and the product distribution of **3** and **4** remain almost unaltered. When the above reaction was performed at 100 °C using toluene as solvent the rate of the reaction was faster but the product distribution of **3** and **4** was almost unaffected. This reaction was also carried out in the presence of boron trifluoride etherate at room temperature. The addition of boron trifluoride etherate increased the reaction rate and starting material disappeared within few hours. Again the product distribution of **3** and **4** remain unchanged. Also by using hydrogen peroxide as a oxidant in the presence of formic acid at room temperature overnight the ratio of **3** and **4** was unaffected. Performing the reaction with mcpba in dichloromethane in the presence of silica gel, the product distribution of **3** and **4** was slightly changed. The ratio of **3** / **4** became more in favour of **3**.

Scheme 1



Pure **3** was converted to the corresponding *O*-methanesulfonyl derivative upon treatment of **3** with methanesulfonyl chloride in the presence of triethylamine in dichloromethane to give **5** which was directly used in the next step. Compound **5** was treated with adenine in the presence of sodium hydride in dimethylformamide (DMF)[5a,b,9] at 90 °C to afford **6** in 54% yield. The benzyl groups at 3'- and 5'-positions of **6** were removed upon treatment with $Pd(OH)_2$ on C (20%)[10] to give **7** in 91% yield. It is not necessary to perform the reaction in an inert atmosphere[5b]. For the incorporation of **7** into DNA protection of the heterocyclic base is necessary. The adenine base of **7** was protected with a benzoyl group following a literature procedure[11] to afford **8** in 90% yield. The 5'-hydroxyl function of **8** was protected with 4-monomethoxytrityl group to yield **9** in 75% yield.

Scheme 2

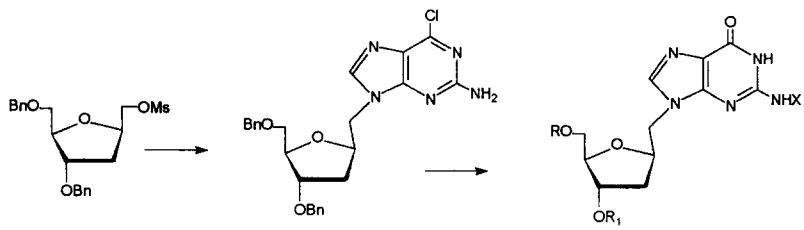


3 5

6: R = R_1 = Bn, X = H
7: R = R_1 = H, X = H
8: R = R_1 = H, X = Bz
9: R = MMTr, R_1 = H, X = B

For the synthesis of **10,** compound **5** was treated with 6-chloro-2-aminopurine in the presence of potassium carbonate in DMF at 90 °C to give the desired product **10** in 55% yield. The 6-chloro-2-aminopurine moiety of **10** was converted to the corresponding guanine derivative upon treatment with aqueous trifluoroacetic acid[12] at room temperature for 48 h to afford **11** in 82% yield. The benzyl protecting groups at 3'- and 5'-position of **11** were removed using the same procedure as described for **7** to afford **12** in 74% yield. The 2-amino function of **12** was protected with isobutyryl group following a literature procedure to give **13** which was directly treated with 4-monomethoxytrityl chloride in pyridine to give **14** (68% in two steps).

Scheme 3



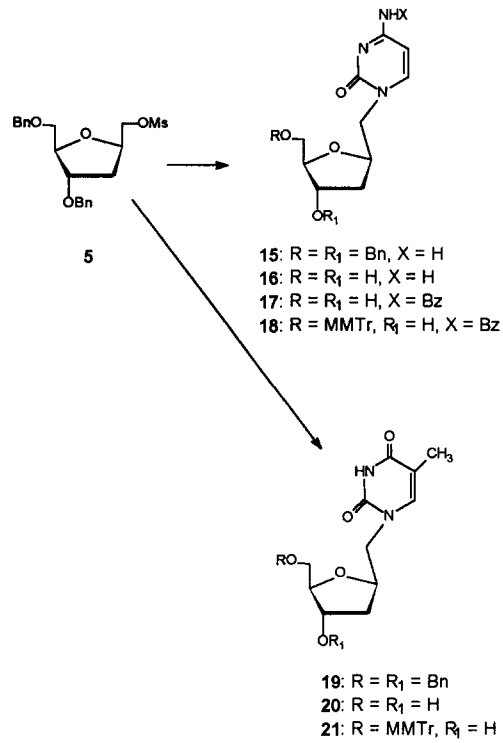
5 10

11: R = R_1 = Bn, X = H
12: R = R_1 = H, X = H
13: R = R_1 = H, X = ib
14: R = MMTr, R_1 = H, X = i

Treatment of **5** with cytosine in the presence of cesium carbonate[5b,13] in DMF at 90 °C gave **15** in a yield of 59% along with the corresponding O^2-isomer (not shown) in 16% yield. The benzyl protection of **15** was deblocked using the above reaction condition to give **16** (93%). The 6-amino function of **16** was protected with benzoyl group to give **17** in 75% yield. The 5'-hydroxyl function of **17** was converted to the corresponding 5'-*O*-MMTr derivative to afford **18** in 67% yield. Compound **19** was synthesised upon treatment of **5** with thymine, potassium carbonate and sodium iodide[5b,14] in DMF at 90 °C in rather low yield (19%). The yield was not optimised. The benzyl groups of **19** were removed to afford **20** in 93% yield. Finally, **20** was treated with 4-

monomethoxytrityl chloride in pyridine to give **21** in 85% yield. Compounds **9**, **14**, **18** and **21** could be converted to their phosphoramidites and these compounds were used to synthesize oligonucleotides[15].

Scheme 4

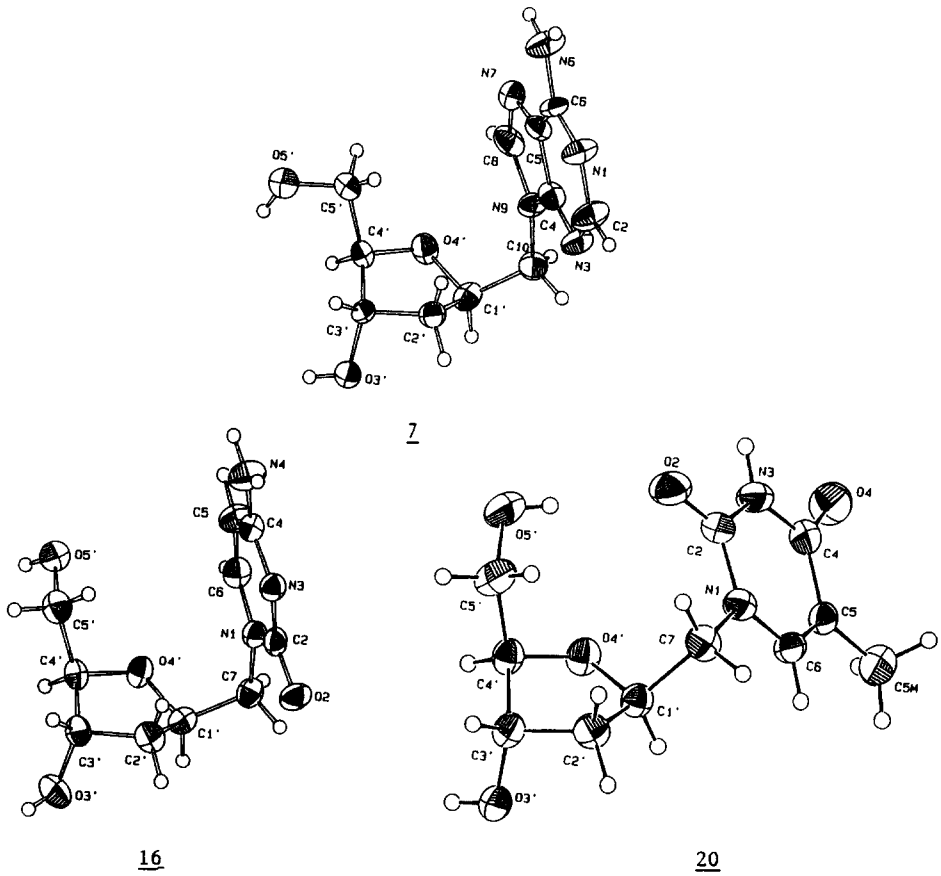


Determination of configuration at C1/C1'-position of 3-21

Determination of configuration at C1 center of **3** and **4** could not be carried out unambiguously as the coupling constants ($J_{1,2}$ and $J_{1,2'}$) of **3** could not be extracted from its ^{1}H-NMR spectrum. Moreover, 1D NOE experiment was problemetic at this stage due to the overlapping of sugar protons with benzyl protons. An indication for the configuration of **3** and **4**, however, could be found in the shielding of protons, H-1 of **3** appears downfield compared to H-1 of **4** in its ^{1}H-NMR spectrum. This should be expected for **3** due to the anisotropic effect of 3-*O*-benzyl group over H-1 when they are in cis orientation. Also, H-3 of **3** was more shielded compared to H-3 of **4**. These observations are consisted with literature data[16]. The 1D NOE experiment of **7**, which was prepared using **3**, at 500 MHz clearly established its β configuration at C1-position. This subsequently also establish the β-configuration of **3** at C1-position. The big coupling constants of $J_{1',2'}$ = 3.9-6.1 Hz and $J_{1',2''}$ = 5.9-9.9 Hz and small coupling constant of $J_{3',4'}$ = 1.9 - 2.9 Hz in **6** - **21** clearly suggests south conformation, of the sugar moiety, which puts the bulky C1'-substituent at the pseudoequatorial position. Simple model building shows that the pseudoeqatorial position of bulky C1'-substituent is possible only in β-

configuration at C1'-position with south conformation. These observations establish the β configuration at C1'-position in **6 - 21**. The site of alkylation of the heterocyclic bases is confirmed by ^{13}C-NMR spectra which is in agreement with reported data.[5b] An unambiguous determination of the configuration followed from X-ray structures of the adenosine **7**, cytosine **16** and thymine **20** analogues. Crystals were obtained by slow evaporation methods. Crystals were mounted on a Stoe STADI4 diffractometer with graphite monchromator and Mo*K*α radiation. Unit cell parameters were known from a least-squares analysis of 24 reflections. Intensity data were collected by ω scan technique. No significant fluctuations in standard reflections (three measured each hour) were observed. The structures were solved by direct methods using SIR92[17] and refined on F^2 by full-matrix least-squares using SHELXL93[18] with anisotropic temperature factors for the non-H atoms and 'riding' H-atoms. ZORTEP[19] was used for molecular graphics. PARST[20] and local programs were used to prepare material for publication. An interesting observation is the opposite orientation of the pyrimidine base in cytosine **16** and thymine **20** analogues.

Figure 1 : Structure of compounds **7**, **16** and **20** as determined by X-ray crystallography.



7

16 **20**

Table 1 : Details of Crystallographic Data Collections and Refinements

	20	**16**	**7**
Empirical formula	$C_{11}H_{16}N_2O_5$	$C_{10}H_{15}N_3O_4$	$C_{11}H_{15}N_5O_3$
Formula weight	256.26	241.25	265.28
Temperature	293(2)	293(2)	293(2)
Wavelength	0.71069	0.71069	0.71069
Crystal color	colourless	colourless	colourless
Crystal system	orthorhombic	monoclinic	orthorhombic
Space group	$P\,2_12_12_1$	$P\,2_1$	$P\,2_12_12_1$
Unit cell dimensions a = b = c = β =	 4.848(3) 12.718(7) 19.29(1)	 7.242(5) 9.346(6) 8.571(6) 105.73(5)	 6.756(6) 9.272(7) 18.91(1)
Volume	1189(1)	558.3(7)	1185(2)
Z	4	2	4
Density (calculated)	1.431 Mg m^{-3}	1.435 Mg m^{-3}	1.487 Mg m^{-3}
Absorption coefficient	0.114	0.112	0.110
$F(000)$	544	256	560
Crystal size (mm)	0.4 x 0.4 x 0.2	0.5 x 0.3 x 0.15	0.3 x 0.1 x 0.1
θ range	1.92 to 25.00	2.47 to 24.98	2.00 to 25.00
Index ranges h k l	-5 to 1 -1 to 15 -1 to 22	-8 to 8 0 to 11 -10 to 10	-1 to 8 -1 to -11 -1 to 22
Reflections collected	1852	2091	1845
Independent reflections R_{int} =	1610 0.0156	1048 0.0292	1549 0.0633
Observed reflections	1330	897	858
Data/parameters	1610/167	1048/157	1549/175
Goodness-of-fit on F^2	1.039	1.049	1.002
Weighting scheme (a/b) $w = 1/\sigma^2(F_O^2) + (aP)^2 + bP$ with $P = (\max(F_O)^2, Fo+2F_c^2)/3$	0.0469/0.0	0.0350/0.0176	0.0374/0.0
Final R indices $[F_O>4\sigma(F_O)]$	0.0337	0.0279	0.0570
R indices (all data)	0.0856	0.0681	0.1670
Extinction coefficient	0.020(3)	0.030(5)	0.009(2)
Largest diff. peak/hole (e.Å^{-3})	0.15/-0.12	0.13/-0.13	0.21/-0.23
Shift/esd Max/Mean	<0.001/<0.001	<0.001/0.001	0.006/<0.001

EXPERIMENTAL

Melting points were determined in capillary tubes with a Buchi-Tottoli apparatus and are uncorrected. The ^{1}H-NMR spectra and ^{13}C-NMR spectra were determined with a Varian Gemini-200 spectrometer using tetramethylsilane as internal standard or at 2.50 ppm for the ^{1}H-NMR spectra and 39.6 or 76.9 ppm for ^{13}C-NMR spectra. The symbols s, d, dd, ddd, t, m or br.s are used as s = singlet, d = doublet, dd = double of doublet, ddd = double of double of doublet, t = triplet, m = multiplet and br. s = broad singlet. High resolusion mass spectra were recorded on a Kratos Concept 1H mass spectrometer. Column chromatography was performed on silica gel (0.060-0.200 nm or 0.030-0.075 nm). Toluene was dried using sodium and benzophenone (benzophenone ketyl). X-ray diffraction intensities were measured on a Stoe STADI4 diffractometer using graphite-monochromated Mo Kα radiation. Crystal data collection and refinement parameters are listed in Table 1. The atomic coordinates and other data for 7, **16** and **20** is deposited in the Cambridge Crystallographic Data Centre. This data can be obtained, on request, from the Director, Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge, CB2 1EZ, UK.

1,3-(R)-*O*-Dibenzyl-2-(S)-hydroxy-5-hexene (2).

Butyl lithium (60 mL of a 1.6 M solution in hexane) was added to a stirred suspension of 33.75 g (94.5 mmol) methyl triphenylphosphonium bromide in 380 mL of dry toluene under an argon atmosphere and the reaction mixture was further stirred at room temperature for 2 h. A solution of compound **1** (12.0 g, 37.8 mmol) in 50 mL of dry toluene was added slowly to this mixture using a dropping funnel and after addition, the reaction mixture was heated at 50 °C for 10 h. The reaction mixture was cooled to room temperature, 100 mL of water was added and the reaction mixture was extracted with ethyl acetate (2 x 300 mL). The combined organic layer was successively washed with saturated ammonium chloride solution, with water and concentrated in vacuo. The crude reaction mixture was purified by a silica gel column chromatography to give 8.4g of **2** (70%) as an oil. ^{1}H-NMR ($CDCl_3$): 7.41-7.18 (m, 10H) arom; 5.90 (m, 1H) H5; 5.10 (m, 2H) H6 and H6'; 4.50 (m, 4H) Ar-CH_2; 3.85 (m, 1H) H2; 3.70-3.41 (m, 3H) H3', H1 and H1'; 2.41 (m, 2H) H4 and H4'. ^{13}C-NMR ($CDCl_3$): 134.7, 128.4, 127.9, 127.7, 117.4, 79.1, 73.5, 72.3, 71.6, 71.1 and 34.8. FAB HRMS m/z 313.1795 for $(M + H)^+$ (calcd. for $C_{20}H_{25}O_3$, 313.1803).

1-*C*-Hydroxymethyl-3,5-*O*-dibenzyl-2-deoxy-β-D-ribose (3) and 1-*C*-Hydroxymethyl-3,5-*O*-dibenzyl-2-deoxy-α-D-ribose (4).

To a solution of 6.6 g (21.1 mmol) of **2** in 100 mL dichloromethane was added 7.28 g (42.2 mmol) m-chloroperbenzoic acid and the reaction mixture was left at room temperature for 48 h. The reaction mixture was poured into aqueous sodium sulphite and extracted with dichloromethane. The organic phase was washed with

saturated aqueous sodium bicarbonate solution until all benzoic acid was removed. The organic layer was concentrated in vacuo and the crude reaction mixture was purified by a silica gel column chromatography to give **3** (3.2 g, 46.2%) and **4** (2.6 g, 37.5%). Compound **3**, ^{1}H-NMR ($CDCl_3$): 7.40-7.10 (m, 10H) arom; 4.50 (m, 4H) Ar$C\underline{H}_2$; 4.30 (m, 1H) H1; 4.10 (m, 2H) H3 and H4; 3.80 (dd, $J_{1,6}$ = 2.6 Hz, $J_{6,6'}$ = 11.9 Hz, 1H) H6; 3.68-3.48 (m, 2H) H5' and H5"; 3.42 (dd, $J_{1,6'}$ = 3.4 Hz, 1H) H6'; 2.0 (m, 2H) H2' and H2". ^{13}C-NMR ($CDCl_3$): 128.5, 127.7, 83.3, 80.8, 79.4, 73.5, 71.4, 70.7, 64.3 and 33.5. FAB HRMS m/z 351.1572 for $(M + Na)^+$ (calcd. for $C_{20}H_{24}O_4Na$, 351.1572). Compound **4**, ^{1}H-NMR ($CDCl_3$): 7.40-7.15 (m, 10H) arom; 4.50 (m, 4H) Ar$C\underline{H}_2$; 4.23 (m, 2H) H3 and H4; 4.10 (m, 1H) H1; 4.20-3.90 (m, 4H) H5', H5", H6, H6'; 2.22 (ddd, $J_{1,2}$ = 5.0 Hz, $J_{2,3}$ = 1.4 Hz, $J_{2,2'}$ = 13.1 Hz) H2; 1.90 (ddd, $J_{1,2'}$ = 3.0 Hz, $J_{2',3}$ = 3.9 Hz, 1H) H2'. ^{13}C-NMR ($CDCl_3$): 128.5, 128.2, 127.8, 82.7, 80.6, 79.5, 73.5, 71.5, 70.9, 65.0 and 33.6. FAB HRMS m/z 351.1588 for $(M + Na)^+$ (calcd. for $C_{20}H_{24}O_4Na$, 351.1572).

1-*C*-(Methanesulfonyloxy)methyl-3,5-*O*-dibenzyl-2-deoxy-β-D-ribose (5).

To an ice-cold solution of 9.5 g, (29.0 mmol) **3** in 290 mL of dichloromethane was added 6.04 mL (43.5 mmol) of triethylamine and 3.38 mL, (43.5 mmol) of methanesulfonyl chloride. The reaction mixture was stirred in ice-water bath for 60 min. After addition of 50 mL water the organic layer was separated and washed with saturated aqueous $NaHCO_3$ and with water. The organic layer was concentrated in vacuo to give 11.8 g (100%) of **5** and this crude material was used in the next step without further purification, ^{1}H-NMR ($CDCl_3$): 7.42-7.18 (m, 10H) arom; 4.60-4.11 (m, 8H) $ArCH_2$, H1, H4, H6 and H6; 4.08 (m, 1H) H3; 3.50 (dd, $J_{4,5}$ = 4.4 Hz, $J_{5,5'}$ = 10.2 Hz, 1H) H5; 3.45 (dd, $J_{4,5'}$ = 5.0 Hz, 1H) H5' 2.96 (s, 3H) OMs; 2.08 (ddd, $J_{1,2}$ = 5.5 Hz, $J_{2',3}$ = 1.9 Hz, $J_{2,2'}$= 13.2 Hz, 1H) H2; 1.81 (ddd, $J_{1,2'}$= 9.5 Hz, $J_{2'3}$ = 6.0 Hz, 1H) H2' ^{13}C-NMR ($CDCl_3$) 137.9, 137.8, 128.4, 127.6 (arom); 83.9, 80.5, 76.3 (C1; C3 and C4); 73.4, 71.2, 71.0, 70.7 ($ArCH_2$, C5 and C6; 37.6 (OMs) and 33.9 (C2).

9-*N*-[(3',5'-*O*-Dibenzyl-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]adenine (6).

A mixture of 1.01 g (7.5 mmol) of adenine, 225 mg (7.5 mmol) of 60% dispersion of NaH in 50 mL of DMF was stirred at 90 °C for 60 min. Then 2.03 g (5.0 mmol) of crude **5** in 10 mL DMF was added and the reaction mixture was kept at 90 °C for 3 h. The reaction mixture was cooled to room temperature and the solvent was removed in vacuo. The residue was dissolved in 100 mL of dichloromethane, washed with saturated aqueous $NaHCO_3$ and water respectively. The organic layer was concentrated in vacuo and purified by silica gel column chromatography to afford 1.2 g (54%) of **6.** ^{1}H-NMR ($CDCl_3$): 8.40 (s, 1H) H2; 7.92 (s, 1H) H8; 7.41-7.19 (m, 10H) arom; 5.90 (br,s; 2H) NH_2; 4.48 (m, 4H) Ar$C\underline{H}_2$; 4.50 (m, 1H) H1'; 4.42 (dd, $J_{1',6'}$ = 3.0 Hz, 1H) H6'; 4.30 (dd, $J_{1',6"}$ = 5.4 Hz, $J_{6',6"}$ = 14.3 Hz, 1H) H6"; 4.16 (m, $J_{3',4'}$ = 2.3 Hz, 1H) H4'; 3.90 (m, 1H) H3'; 3.42 (dd, $J_{4',5'}$ = 4.7 Hz, $J_{5',5"}$ = 10.1 Hz, 1H) H5'; 3.33 (dd, $J_{4',5"}$ = 4.8 Hz, 1H) H5"; 2.10 (ddd, $J_{2',3'}$ = 1.7

Hz, $J_{1',2'}$ = 5.6 Hz, 1H) H2'; 1.60 (ddd, $J_{2'',3'}$ = 6.0 Hz, $J_{1',2''}$ = 9.8 Hz, $J_{2',2''}$ = 13.1 Hz, 1H) H2''. ^{13}C-NMR ($CDCl_3$): 155.4 (C6); 152.8 (C2); 150.1 (C4); 141.8 (C8); 137.8, 137.7, 128.3, 128.0, 127.5 (arom); 83.7, 80.4, 76.8 (C1', C3' and C4'); 73.2, 71.0; 70.5 (Ar$\underline{C}H_2$ and C5'); 46.0 (C6') and 34.6 (C2'). FAB HRMS m/z 446.2190 for $(M + H)^+$ (calcd. for $C_{25}H_{28}N_5O_3$, 446.2192).

9-*N*-[(2'-Deoxy-β-D-*ribo*-pentofuranosyl)methyl]adenine (7).

A mixture of 1.1 g (2.5 mmol) of **6** and 1.1 g of Pd $(OH)_2$ on C (20%) in 25 mL cyclohexene and 75 mL ethanol,was kept at reflux temperature for 30 h. The reaction mixture was filtered through a celite pad. The filtrate was concentrated in vacuo to yield a white powder which was titurated with dichloromethane to afford pure 7 (595 mg, 91%). ^{1}H-NMR (DMSO-d_6). 8.18 (s, 1H), 8.08 (s, 1H) H2 and H8; 7.20 (br,s, 2H) NH_2; 4.95 (d, 1H) 3'OH; 4.76 (t, 1H) 5'OH; 4.35 (m, 1H) H1'; 4.28 (dd, $J_{1'6'}$ = 3.4 Hz, 1H) H6'; 4.18 (dd, $J_{1',6''}$ = 7.0 Hz, $J_{6',6''}$ = 14.3 Hz, 1H) H6''; 4.0 (m, $J_{3',4'}$ = 1.9 Hz, 1H) H3'; 3.62 (m, 1H) H4'; 3.28 (dd, $J_{4',5'}$ = 4.9 Hz, $J_{5',5''}$ = 11.6 Hz, 1H) H5'; 3.19 (dd, $J_{4',5''}$ = 5.2 Hz, 1H) H5''; 1.80 (ddd, $J_{2',3'}$ = 3.0 Hz, $J_{1',2'}$ = 6.1 Hz, 1H) H2'; 1.65 (ddd, $J_{2'',3'}$ = 5.9 Hz, $J_{1',2''}$ = 8.6 Hz, $J_{2',2''}$ = 12.9 Hz, 1H) H2''. ^{13}C-NMR (DMSO-d_6): 156.1 (C6), 152.5 (C2), 149.8 (C4), 141.7 (C8), 118.6(C5), 87.5, 76.2, 71.6 (C1',C3' and C4'), 62.1 (C5'), 47.0 (C6') and 37.5 (C2'). m.p 220 °C, FAB HRMS m/z 266.1245 for $(M + H)^+$ (calcd. for $C_{11}H_{16}N_5O_3$, 266.1253). Anal. ($C_{11}H_{15}N_5O_3$) calculated for C: 49.81, H: 5.70 and N: 26.40 found C: 49.57, H: 5.63 and N: 26.04.

9-*N*-[(2'-Deoxy-β-D-*ribo*-pentofuranosyl)methyl]-N^6-benzoyladenine (8).

Following with a literature procedure[11] **8** was prepared. Treatment of 7 (540 mg, 2.03 mmol), trimethylsilyl chloride (1.30 mL, 10.15 mmol) and benzoyl chloride (1.18 mL, 10.15 mmol) in pyridine yielded **8** (680 mg, 90%) after the usual workup procedure. ^{1}H-NMR (DMSO-d_6): 8.70 (s, 1H) H2; 8.40 (s, 1H) H8; 8.0 (m, 2H) arom; 7.70-7.30 (m, 3H) arom; 5.0 (br.s, 1H) 3'OH; 4.72 (br.s, 1H) 5'OH; 4.35 (m, 3H) H1', H6' and H6''; 4.0 (br.s, 1H) H4'; 3.62 (br.s, 1H) H3'; 3.28 (m, 2H) H5',H5''; 1.75 (m, 2H) H2' and H2''. ^{13}C-NMR (DMSO-d_6): 165.8 ($\underline{C}$ONH); 152.5, 151.5, 149.8 and 145.6 (C6, C2, C8, and C4); 133.4, 132.6, 128.6 and 128.4 (arom); 124.6 (C5); 87.3, 75.9, 71.5 (C1', C3' and C4'); 61.9 (C5'); 47.2 (C6') and 37.3 (C2'). FAB HRMS m/z 370.1520 for $(M + H)^+$ (calcd. for $C_{18}H_{20}N_5O_4$, 370.1515).

9-*N*-[(5'-*O*-MMTr-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]-N^6-benzoyladenine (9).

A mixture of **8** (600 mg, 1.62 mmol) and 4-monomethoxytrityl chloride (724 mg, 2.34 mmol) in pyridine was stirred at room temperature overnight. The reaction mixture was poured into ice-water (20 mL) and extracted with dichloromethane (2 x 60 mL). Combined organic layer was concentrated in vacuo and co-evaporated with toluene. The residue was purified by a silica gel column chromatography to afford pure **9** (780 mg, 75%) as a foam. ^{1}H-NMR ($CDCl_3$): 9.32 (br.s, 1H) N$\underline{H}$CO; 8.77 (s, 1H) H2; 8.02 (m, 3H) H8 and arom; 7.61-6.75 (m,

17H) arom; 4.49 (m, 2H) H1' and H6'; 4.28 (m, 1H) H3'; 4.20 (dd, $J_{1',6''}$ = 7.3 Hz, $J_{6',6''}$ = 15.1 Hz, 1H) H6"; 3.93 (m, 1H) H4'; 3.77 (s, 3H) OCH_3; 3.21 (dd, $J_{4',5'}$ = 4.5 Hz, $J_{5',5''}$ = 9.8 Hz, 1H) H5'; 3.05 (dd, $J_{4',5''}$ = 5.1 Hz, 1H) H5"; 2.0 (ddd, $J_{1',2'}$ = 5.6 Hz, $J_{2',3'}$ = 2.2 Hz, $J_{2',2''}$ = 13.0 Hz, 1H) H2'; 1.75 (ddd, $J_{1',2''}$ = 9.3 Hz, $J_{2'',3'}$ = 6.1 Hz, 1H) H2". ^{13}C-NMR ($CDCl_3$): 164.7, 158.6, 152.6, 152.0, 149.4, 144.0, 135.2, 133.8, 132.7, 130.3, 128.8, 128.3, 127.9, 127.0, 122.1, 113.6 (CONH, arom, C2, C4, C5, C6 and C8); 86.5 (MMTr); 86.2, 76.3, 73.7 (C1', C3' and C4'); 64.1 (C5'); 55.2 (OCH_3); 47.0 (C6') and 37.9 (C2'). FAB HRMS m/z 664.2538 for $(M + Na)^+$ (calcd. for $C_{38}H_{35}O_5N_5Na$, 664.2536)

9-*N*-[(3',5'-*O*-Dibenzyl-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]-6-chloro-2-aminopurine (10).

A mixture of 2.43 g (6.0 mmol) of crude **5**, 1.24 g (9.0 mmol) of K_2CO_3 and 1.52 g (9.0 mmol) of 6-chloro-2-aminopurine in 60 mL of dry DMF was heated at 90 °C for 18 h. The reaction mixture was cooled to room temperature, the solvent was removed in vacuo. The residue was dissolved in ethyl acetate (150 mL) which was successively washed with saturated $NaHCO_3$ and water. The organic layer was concentrated in vacuo. The crude mixture was purified by a silica gel column chromatography to give pure **10** (1.6 g, 55%). ^{1}H-NMR ($CDCl_3$): 7.82 (s, 1H) H8; 7.42-7.18 (m, 10H) arom; 5.18 (br.s, 2H) NH_2; 4.58-4.42 (m, 5H) H1' and Ar CH_2; 4.28 (dd, $J_{1',6'}$ = 3.2 Hz, $J_{6',6''}$ = 14.5 Hz, 1H) H6'; 4.15 (dd, $J_{1',6''}$ = 5.4 Hz, 1H) H6"; 4.13 (m, 1H) H4'; 3.95 (m, $J_{3',4'}$ = 2.5 Hz, 1H) H3'; 3.43 (dd, $J_{4',5'}$ = 4.5 Hz, $J_{5',5''}$ = 10.1 Hz, 1H) H5'; 3.35 (dd, $J_{4',5''}$ = 4.7 Hz, 1H) H5"; 2.08 (ddd, $J_{1',2'}$ = 5.6 Hz, $J_{2',3'}$ = 1.8 Hz, 1H) H2'; 1.58 (ddd, $J_{1',2''}$ = 9.9 Hz, $J_{2'',3'}$ = 6.1 Hz, $J_{2',2''}$ = 13.2 Hz, 1H) H2". ^{13}C-NMR ($CDCl_3$): 159.0 (C2); 154.0 (C4); 151.1 (C6); 143.9 (C8); 137.8, 128.4, 127.7 (arom); 83.4, 80.6, 76.6 (C1',C3' and C4'); 73.4, 71.1, 70.6 (ArCH_2 and C5'); 46.0 (C6') and 34.9 (C2'). FAB HRMS m/z 480.1789 for $(M + H)^+$ (calcd. for $C_{25}H_{27}N_5O_3Cl$, 480.1802).

9-*N*-[(3',5'-*O*-Dibenzyl-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]guanine (11).

A solution of 1.4 g (2.91 mmol) of **10** in 30 mL 75% trifluoroacetic acid in water was kept at room temperature for 48 h. The solvent was removed in vacuo and the residue was treated with 40 mL of MeOH : NH_4OH (10 : 1). The solvent was removed in vacuo and coevaporated with toluene. The residue was purified by a silica gel column chromatography to give pure **11** (1.1 g, 82%). ^{1}H-NMR (DMSO-d_6): 10.55 (br.s, 1H) NH; 7.54 (s, 1H) H8; 7.41-7.18 (m, 10H) arom; 6.42 (br.s, 2H) NH_2; 4.49 (m, 4H) $ArCH_2$; 4.35 (m, 1H) H1'; 4.08 (dd, $J_{1',6'}$ = 4.4 Hz, $J_{6',6''}$ = 14.2 Hz, 1H) H6'; 3.95 (m, 3H) H4', H3' and H6"; 3.35 (dd, $J_{4',5'}$ = 5.0 Hz, $J_{5',5''}$ = 10.4 Hz, 1H) H5'; 3.29 (dd, $J_{4',5''}$ = 5.7 Hz, 1H) H5"; 1.97 (ddd, $J_{1',2'}$ = 5.1 Hz, $J_{2',2''}$ = 13.2 Hz, 1H) H2'; 1.65 (ddd, $J_{1';2''}$ = 9.5 Hz, $J_{2'',3'}$ = 5.8 Hz, 1H) H2". ^{13}C-NMR (DMSO-d_6): 157.2 (C6); 153.7 (C2); 151.7 (C4); 138.5, 138.4, 128.6, 127.9 (arom); 116.4 (C5); 83.3, 80.5 and 76.6 (C1', C3' and C4'); 72.7, 70.9 and 70.4 ($ArCH_2$ and C5'); 46.5 (C6') and 34.8 (C2'). FAB HRMS m/z 462.2131 for $(M + H)^+$ (calcd. for $C_{25}H_{28}N_5O_4$, 462.2141).

9-*N*-[(2'-Deoxy-β-D-*ribo*-pentofuranosyl)methyl]guanine (12).

A reaction mixture containing 1.0 g (2.17 mmol) of **11** and 1.0 g of $Pd(OH)_2$ on C(20%) in 25 mL cyclohexene and 75 mL of ethanol was heated at reflux for 16 h and filtered through a celite. The solvent was removed in vacuo and the residue was titurated with dichloromethane to give **12** (450 mg, 74%) as a white powder. ^{1}H-NMR (DMSO-d_6): 10.71 (br.s, 1H) NH; 7.62 (s, 1H) H8; 6.50 (br.s, 2H) NH_2; 4.98 (d, $J_{3',OH}$ = 3.7 Hz, 1H) 3'OH; 4.68 (t, $J_{5',OH} = J_{5'',OH}$ = 5.5 Hz, 1H) 5'OH; 4.25 (m, 1H) H1'; 4.02 (dd, $J_{1',6'}$ = 4.0 Hz, $J_{6',6''}$ = 14.0 Hz, 1H) H6'; 3.98 (br.s, 1H) H3'; 3.92 (m, $J_{1',6''}$ = 6.7 Hz, 1H) H6"; 3.58 (m, 1H) H4'; 3.29 (m, $J_{4',5'}$ = 4.8 Hz, $J_{5',5''}$ = 11.5 Hz, 1H) H5'; 3.18 (m, $J_{4',5''}$ = 5.6 Hz, 1H) H5"; 1.72-1.48 (m, $J_{1',2'}$ = 5.6 Hz, $J_{1',2''}$ = 8.0 Hz, $J_{2',2''}$ = 13.1 Hz, 2H) H2' and H2". ^{13}C-NMR (DMSO-d_6): 157.0 (C6); 153.7 (C2); 151.4 (C4); 138.4 (C8); 116.3 (C5); 87.5, 76.0, 71.7 (C1', C3' and C4'); 62.2 (C5'); 46.7 (C6') and 37.5 (C2'). FAB HRMS m/z 282.1205 for $(M + H)^+$ (calcd. for $C_{11}H_{16}N_5O_4$, 282.1202). Anal. ($C_{11}H_{15}N_5O_4$ + 0.9 CH_2Cl_2) calculated for C: 39.96, H: 4.73 and N: 19.58 found C: 40.17, H: 5.00 and N: 19.61.

9-*N*-[(2'-Deoxy-β-D-*ribo*-pentofuranosyl)methyl]-N^2-isobutyrylguanine (13).

Compound **13** was prepared according to a literature procedure[11] using **12** (400 mg, 1.42 mmol), trimethylsilyl chloride (0.9 mL, 7.1 mmol) and isobutyric anhydride (1.16 mL, 7.1 mmol) in 10 mL of pyridine. After usuall workup the product was crystallized from water and was used directly for the next step. This compound contains substantial amount of salt and no good resolution NMR spectrum could be obtained.

9-*N*-[(5'-*O*-MMTr-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]-N^2-isobutyryl-guanine (14).

Compound **13** was treated with 864 mg (2.8 mmol) of 4-monomethoxytrityl chloride in 15 mL pyridine at room temperature overnight. The reaction mixture was poured into ice-water (20 mL) which was extracted with dichloromethane (2 x 60 mL). The combined organic layer was concentrated in vacuo and coevaporated with toluene. The residue was purified by a silica gel column chromatography to give pure **14** (600 mg, 68% in two steps). ^{1}H-NMR ($CDCl_3$): 12.06 (br.s, 1H) NH; 9.71 (br.s, 1H) CONH; 7.62 (s, 1H) H8; 7.41-6.77 (m, 14H) arom; 4.48 (m, 1H) H1', 4.20 (m, 2H) H3' and H6'; 3.91 (m, 2H) H4' and H6"; 3.78 (s, 3H) $OC\underline{H}_3$; 3.17 (dd, $J_{4',5'}$ = 4.7 Hz, $J_{5',5''}$ = 9.9 Hz, 1H) H5'; 2.92 (dd, $J_{4',5''}$ = 4.8 Hz, 1H) H5"; 2.20 (br.s, 1H) 3'OH; 2.50 (m, 1H) $C\underline{H}(CH_3)_2$; 1.91 (m, $J_{1',2'}$ = 4.2 Hz, $J_{2',2''}$ = 13.0 Hz, 1H) H2'; 1.71 (m, $J_{2'',3'}$ = 4.8 Hz, 1H) H2"; 1.08 (d, $J_{CH,CH3}$ = 3.4 Hz, 3H) isobutyryl methyl; 0.98 (d, $J_{CH,CH3}$ = 3.4 Hz, 3H) isobutyryl methyl. ^{13}C-NMR ($CDCl_3$): 179.5, 158.7, 155.9, 148.9, 147.7, 144.3, 140.2, 135.4, 130.4, 128.4, 127.9, 127.1, 120.3, 113.2 (arom); 86.5 (MMTr); 86.3, 76.5 and 73.6 (C1', C3' and C4'); 64.3 (C5'); 55.3 (OCH_3); 47.5 (C6'); 38.2, 36.1 (C2' and $C\underline{H}(CH_3)_2$); 19.0 (isobutyryl methyl). FAB HRMS m/z 646.2619 for $(M + Na)^+$ (calcd. for $C_{35}H_{37}O_6N_5Na$, 646.2641).

1-*N*-[(3',5'-*O*-Dibenzyl-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]cytosine (15).

A mixture of 2.43 g (6.0 mmol) of crude **5**, 999 mg (9.0 mmol) of cytosine and 3.9 g (12.0 mmol) $CsCO_3$ in DMF was heated at 90 °C for 18 h. The reaction mixture was cooled to room temperature and the solvent was removed in vacuo. The residue was dissolved in 150 mL ethylacetate and was successively washed with saturated aqueous $NaHCO_3$ and water. The organic phase was concentrated in vacuo and purified by a silica gel column chromatography to give pure **15** (1.5 g, 59%) along with 400 mg of the corresponding O^2-isomer (not shown in fig.). ^{1}H-NMR ($CDCl_3$): 7.45-7.18 (m, 11H) arom and H6; 5.55 (d, $J_{5,6}$ = 7.2 Hz, 1H) H5; 4.58-4.38 (m, 5H) $ArCH_2$ and H1'; 4.10 (m, 1H) H4'; 4.08 (dd, $J_{1',6'}$ = 2.6 Hz, 1H) H6'; 3.98 (m, $J_{3',4'}$ = 2.9 Hz, 1H) H3'; 3.78 (dd, $J_{1',6''}$ = 6.2 Hz, $J_{6',6''}$ = 13.9 Hz, 1H) H6"; 3.42 (br.d, 2H) H5' and H5"; 2.12 (ddd, $J_{1',2'}$ = 5.4 Hz, $J_{2',3'}$ = 1.9 Hz, 1H) H2'; 1.72 (ddd, $J_{1',2''}$ = 9.3 Hz, $J_{2'',3'}$ = 5.5 Hz, $J_{2',2''}$ = 13.4 Hz, 1H) H2". ^{13}C-NMR ($CDCl_3$): 165.7 (C4); 156.6 (C2); 146.8 (C6); 137.7, 128.2, 127.4 (arom); 93.3 (C5); 83.3, 80.2 and 77.0 (C1', C3' and C4'); 73.1, 70.9 and 70.5 ($ArCH_2$ and C5'); 51.4 (C6'), 34.4 (C2'). FAB HRMS m/z 422.2083 for $(M + H)^+$ (calcd. for $C_{24}H_{28}N_3O_4$, 422.2079). ^{1}H-NMR ($CDCl_3$) of O^2-isomer: 7.98 (d, $J_{5,6}$ = 5.9 Hz, 1H) H6; 7.42-7.18 (m, 10H) arom; 6.08 (d, 1H) H5; 5.12 (br.s, 2H) NH_2; 4.58-4.42 (m, 5H) H1' and $ArCH_2$; 4.35 (br.d, 2H) H6' and H6"; 4.19 (m, 1H) H4'; 4.08 (m, 1H) H3'; 3.55 (dd, $J_{4',5'}$ = 5.0 Hz, $J_{5',5''}$ = 10.3 Hz, 1H) H5', 3.46 (dd, $J_{4',5''}$ = 5.6 Hz, 1H) H5"; 2.15 (ddd, $J_{1',2'}$ = 5.3 Hz, $J_{2',3'}$ = 2.0 Hz, $J_{2',2''}$ = 13.0 Hz, 1H) H2'; 1.95 (ddd, $J_{1',2''}$ = 8.8 Hz, $J_{2'',3'}$ = 6.4 Hz, 1H) H2". ^{13}C-NMR($CDCl_3$): 165.4, 165.1 (C4 and C2); 157.6 (C6); 138.4, 128.7, 128.4, 128.0 (arom); 99.9 (C5); 83.9, 81.2, 75.9 (C1', C3' and C4'); 73.7, 71.5, 71.3, 68.8 ($ArCH_2$, C5' and C6'); 35.0 (C2'). FAB HRMS m/z 422.2085 for $(M + H)^+$ (calcd. for $C_{24}H_{28}N_3O_4$, 422.2079).

1-*N*-[(2'-Deoxy-β-D-*ribo*-pentofuranosyl)methyl]cytosine (16).

Treatment of **15** (1.41 g, 3.35 mmol) with 1.41 g $Pd(OH)_2$ on C(20%) in cyclohexene (35 mL) and ethanol (95 mL) at reflux temperature for 24 h yielded crude **16** which upon tituration with dichloromethane gave pure **16** (750 mg, 93%). Workup is similar to that of **7**. ^{1}H-NMR (DMSO-d_6): 7.55 (d, $J_{5,6}$ = 7.2 Hz, 1H) H6; 5.64 (d, 1H) H5; 4.92 (br.s, 1H), 4.63 (br.s, 1H) 5'OH and 3'OH; 4.19 (m, 1H) H1'; 4.02 (m, $J_{3',4'}$ = 2.0 Hz, 1H) H3'; 3.81 (dd, $J_{1',6'}$ = 3.2 Hz, $J_{6',6''}$ = 13.7 Hz, 1H) H6'; 3.63-3.50 (m, 2H) H4' and H6"; 3.30 (dd, $J_{4',5'}$ = 4.6 Hz, $J_{5',5''}$ = 11.6 Hz, 1H) H5'; 3.25 (dd, $J_{4',5''}$ = 5.8 Hz, 1H) H5"; 1.75 (ddd, $J_{1',2'}$ = 4.3 Hz, $J_{2',3'}$ = 2.6 Hz, $J_{2',2''}$ = 13.0 Hz, 1H) H2'; 1.62 (ddd, $J_{1',2''}$ = 6.8 Hz, $J_{2'',3'}$ = 5.7 Hz, 1H) H2". ^{13}C-NMR (DMSO-d_6): 166.2 (C4); 156.7 (C2); 147.6 (C6); 93.4 (C5); 87.6, 76.3, 72.0 (C1', C3' and C4'); 62.5 (C5'); 52.7 (C6') and 37.7 (C2'). m.p 200 °C, FAB HRMS m/z 242.1136 for $(M + H)^+$ (calcd. for $C_{10}H_{16}N_3O_4$, 242.1140).

1-*N*-[(2'-Deoxy-β-D-*ribo*-pentofuranosyl)methyl]-N^4-benzoyl-cytosine (17).

According to the known method[11] treatment of **16** (500 mg, 2.48 mmol) with trimethylsilyl chloride (1.56 mL, 12.2 mmol) and benzoyl chloride (1.41 mL, 12.2 mmol) in 25 mL pyridine gave **17** (640 mg, 75%). ^{1}H-NMR (DMSO-d_6): 8.18 (d, $J_{5,6}$ = 7.3 Hz, 1H) H6; 8.0 (m, 2H) arom; 7.68-7.42 (m, 3H) arom; 7.25 (d, 1H) H5; 4.60 (br.s, 2H) 5'OH and 3'OH; 4.30 (m, 1H) H1'; 4.08 (m, 2H) H3' and H6'; 3.80 (dd, $J_{1',6"}$ = 7.5 Hz, $J_{6',6"}$ = 13.4 Hz, 1H) H6"; 3.61 (m, 1H) H4'; 3.30 (dd, $J_{4',5'}$ = 4.5 Hz, 1H) H5'; 3.23 (dd, $J_{4',5"}$ = 4.9 Hz, $J_{5',5"}$ = 11.6 Hz, 1H) H5"; 1.81-1.53 (m, $J_{1',2'}$ = 4.2 Hz, $J_{1',2"}$ = 7.7 Hz, $J_{2',2"}$ = 12.9 Hz, 2H) H2' and H2". ^{13}C-NMR (DMSO-d_6): 167.3 (NHCO); 162.2 (C4); 153.6 (C2); 152.8 (C6); 133.2, 132.9, 128.6 (arom); 95.3 (C5); 87.5, 75.2, 71.8 (C1', C3' and C4'); 62.2 (C5'), 53.2 (C6') and 37.5 (C2'). FAB HRMS m/z 346.1401 for $(M + H)^+$ (calcd. for $C_{17}H_{20}N_3O_5$, 346.1402).

1-*N*-[(5'-*O*-MMTr-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]-N^4-benzoyl-cytosine (18).

Compound **17** (500 mg, 1.45 mmol) was treated with 4-monomethoxytrityl chloride (617 mg, 2.0 mmol) in 15 mL pyridine at room temperature overnight. The reaction mixture was poured into ice-water and extracted with (2 x 75 mL) ethylacetate. The combined organic layer was concentrated in vacuo and coevaporated with toluene. The crude reaction mixture was purified by a silica gel column chromatography to give pure **18** (600 mg, 67%). ^{1}H-NMR ($CDCl_3$): 8.80 (br.s, 1H) NHCO; 7.95-6.75 (m, 21H) arom, H5 and H6; 4.52 (m, 1H) H1'; 4.35 (m, 2H) H3' and H6'; 4.0 (m, 1H) H4'; 3.78 (s, 3H) OCH_3; 3.70 (dd, $J_{1',6"}$ = 7.3 Hz, $J_{6',6"}$ = 13.6 Hz, 1H) H6"; 3.22 (dd, $J_{4',5'}$ = 4.5 Hz, $J_{5',5"}$ = 9.9 Hz, 1H) H5'; 3.09 (dd, $J_{4',5"}$ = 5.0 Hz, 1H) H5". 2.11 (ddd, $J_{1',2'}$ = 5.8 Hz, $J_{2',3'}$ = 1.9 Hz, $J_{2',2"}$ = 13.1 Hz, 1H) H2'; 1.85 (ddd, $J_{1',2"}$ = 9.5 Hz, $J_{2",3'}$ = 6.2 Hz, 1H) H2". ^{13}C-NMR ($CDCl_3$): 162.3, 158.7, 150.4, 144.2, 135.3, 133.2, 130.3, 129.0, 128.4, 127.9, 127.6, 127.1, 113.2 (arom); 96.2 (C5); 86.5 (MMTr); 86.0, 76.0, 73.8 (C1'; C3' and C4'); 64.1 (C5'), 55.3 (OCH_3), 53.4 (C6') and 38.0 (C2'). FAB HRMS m/z 640.2425 for $(M + Na)^+$ (calcd. for $C_{37}H_{35}O_6N_3Na$, 640.2423).

1-*N*-[(3',5'-*O*-Dibenzyl-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]thymine (19).

A mixture of 2.43 g (6.0 mmol) of crude **5**, 1.65 g (12.0 mmol) K_2CO_3, 1.12 g (9.0 mmol) thymine and 1.34 g (9.0 mmol) NaI in 60 ml DMF was stirred at 90 °C for 18 h. The reaction mixture was cooled to room temperature and evaporated in vacuo. The residue was dissolved in 150 mL ethylacetate, washed successively with saturated $NaHCO_3$ and water. The organic layer was concentrated in vacuo and purified by a silica gel column chromatography to afford pure **19** (500 mg, 19%). ^{1}H-NMR ($CDCl_3$): 9.18 (br.s, 1H) NH; 7.42-7.18 (m, 10H) arom; 7.10 (s, 1H) H6; 4.55-4.43 (m, 4H) $ArCH_2$; 4.42 (m, 1H) H1'; 4.12 (m, 1H) H4'; 4.04 (m, 1H) H3'; 3.96 (dd, $J_{1',6'}$ = 2.5 Hz, 1H) H6'; 3.70 (dd, $J_{1',6"}$ = 6.4 Hz, 1H) H6"; 3.44 (br.d, 2H) H5' and H5"; 2.12 (ddd, $J_{2',3'}$ = 2.5 Hz, $J_{1',2'}$ = 5.1 Hz, 1H) H2'; 1.83 (s, 3H) $5CH_3$; 1.71 (ddd, $J_{1',2"}$ = 9.7 Hz, $J_{2",3'}$ = 6.2 Hz,

$J_{2',2''}$ = 15.9 Hz, 1H) H2". ^{13}C-NMR ($CDCl_3$): 164.2 (C4); 151.1 (C2); 141.9 (C6); 137.7, 128.3, 127.5 (arom); 109.5 (C5); 83.6, 80.2, 76.9 (C1', C3' and C4'); 73.3, 71.0, 70.5 ($ArCH_2$ and C5'); 50.2 (C6'); 34.6 (C2') and 12.1 ($5CH_3$). FAB HRMS m/z 437.2078 for $(M + H)^+$ (calcd. for $C_{25}H_{29}N_2O_5$, 437.2076).

1-*N*-[(2'-Deoxy-β-D-*ribo*-pentofuranosyl)methyl]thymine (20).

A mixture of **19** (660 mg, 1.52 mmol), $Pd(OH)_2$ on C (20%) (660 mg) in cyclohexene and ethanol was heated at reflux for 16 h. The reaction mixture was filtered through a celite and the solvent was concentrated in vacuo. Crystallization of the residue in methanol dichloromethane yielded pure **20** (360 mg, 93%). ^{1}H-NMR (DMSO-d_6): 11.20 (br.s, 1H) NH; 7.50 (s, 1H) H6; 4.98 (d, $J_{3',OH}$ = 2.8 Hz, 1H) 3'OH; 4.68 (t, $J_{5',OH} = J_{5'',OH}$ = 4.8 Hz, 1H) 5'OH; 4.21 (m, 1H) H1'; 4.08 (m, 1H) H3'; 3.80 (dd, $J_{1',6'}$ = 3.3 Hz, $J_{6',6''}$ = 13.2 Hz, 1H) H6'; 3.62 (m, 1H) H4'; 3.61 (dd, $J_{1',6''}$ = 7.7 Hz, 1H) H6"; 3.35 (dd, $J_{4',5'}$ = 4.2 Hz, $J_{5',5''}$ = 11.5 Hz, 1H) H5'; 3.26 (dd, $J_{4',5''}$ = 5.2 Hz, 1H) H5"; 1.77 (m, $J_{1',2'}$ = 3.9 Hz, 1H) H2'; 1.76 (s, 3H) $5CH_3$; 1.62 (ddd, $J_{1',2'}$ = 8.8 Hz, $J_{2'',3'}$ = 4.4 Hz, $J_{2',2''}$ = 13.2 Hz, 1H) H2". ^{13}C-NMR (DMSO-d_6): 164.4 (C4); 151.2 (C2); 142.5 (C6); 107.9 (C5); 87.5, 75.9, 71.7 (C1', C3' and C4'); 62.2 (C5'); 50.9 (C6'); 37.4 (C2') and 12.0 ($5CH_3$). m.p 170 °C, FAB HRMS m/z 257.1136 for $(M + H)^+$ (calcd. for $C_{11}H_{17}N_2O_5$, 257.1137). Anal. ($C_{11}H_{16}N_2O_5$ + 0.25 H_2O) calculated for C: 50.37, H: 6.40 and N: 10.58 found C: 50.15, H: 6.43 and N: 10.63.

1-*N*-[(5'-*O*-MMTr-2'-deoxy-β-D-*ribo*-pentofuranosyl)methyl]thymine (21).

A mixture of **20** (330 mg, 1.29 mmol) and 4-monomethoxytrityl chloride (600 mg, 1.94 mmol) in pyridine was kept at room temperature overnight. The reaction mixture was poured into ice-water (15 mL) and extracted with dichloromethane (2 x 40 mL). The combined organic layer was concentrated in vacuo. The residue was purified by a silica gel column chromatography to give pure **21** (580 mg, 85%). ^{1}H-NMR ($CDCl_3$): 9.0 (br.s, 1H) NH; 7.49-6.75 (m, 15H) arom and H6; 4.42 (m, 1H) H1'; 4.30 (m, 1H) H3'; 4.11 (dd, $J_{1',6'}$ = 2.5 Hz, $J_{6',6''}$ = 14.3 Hz, 1H) H6'; 3.95 (m, 1H) H4'; 3.79 (s, 3H) OCH_3; 3.58 (dd, $J_{1',6''}$ = 6.8 Hz, 1H) H6"; 3.25 (dd, $J_{4',5'}$ = 4.5 Hz, $J_{5',5''}$ = 9.8 Hz, 1H) H5'; 3.08 (dd, $J_{4',5''}$ = 5.5 Hz, 1H) H5"; 2.31 (br.s, 1H) 3'OH; 1.98 (ddd, $J_{1',2'}$ = 5.9 Hz, $J_{2',3'}$ = 2.4 Hz, $J_{2',2''}$ = 13.2 Hz, 1H) H2'; 1.80 (m, 1H) H2"; 1.72 (d, $J_{5,CH3}$ = 1.0 Hz, 3H) $5CH_3$. ^{13}C-NMR ($CDCl_3$): 164.2 (C4); 158.7 (arom); 151.2 (C2); 135.3 (C6); 130.3, 128.3, 127.9, 127.1, 113.2 (arom); 110.0 (C5); 86.5 (MMTr); 86.0, 76.8, 73.7 (C1', C3' and C4'); 64.1 (C5'); 55.3 (OCH_3); 51.0 (C6'); 37.7 (C2') and 12.2 ($5CH_3$). FAB HRMS m/z 551.2169 for $(M + Na)^+$ (calcd. for $C_{31}H_{32}O_6N_2Na$, 551.2158).

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REFERENCES

1. Postema, M. H. D. *Tetrahedron* **1992**, *48*, 8545-8599.
2. Nishimura, H.; Mayama, M.; Komatsu, Y.; Kato, H.; Shimaoka, N.; Tanaka, Y. *J. Antibiot. Ser. A* **1964**, *17*, 148-155.
3. Wong, C.-H.; Provencher, L.; Porco, Jr., J. A.; Jung, S.-H.; Wang, Y.-F.; Chen, L.; Wang, R.; Steensma, D. H. *J. Org. Chem.* **1995**, *60*, 1492-1501.
4. Secrist III, J. A. *J. Org. Chem.* **1978**, *43*, 2925-2927.
5. (a) Hoffer, M. *Chem. Ber.* **1960**, *93*, 2777-2781; (b) Vandendriessche, F.; Snoeck, R.; Janssen, G.; Hoogmartens, J.; Aerschot, A. V.; De Clercq, E.; Herdewijn, P. *J. Med. Chem.* **1992**, *34*, 1458-1465.
6. (a) Pougny, J. R.; Nassr, M. A. H.; Sinay, P. *J. Chem. Soc. Chem. Commun.* **1981**, 375-376. (b) Wilcox, C. S.; Thomasco, L. M. *J. Org. Chem.* **1985**, *50*, 546-547. (c) Maryanoff, B.; Nortey, S. O.; Inners, R. R.; Campbell, S. A.; Reitz, A. B. *Carbohydr. Res.* **1987**, *171*, 259-278. (d) Chorghade, M.; Cseke, C. T.; Liu, P. S. *Tetrahedron Asymmetry* **1994**, *5*, 2251-2254.
7. Reitz, A. B.; Nortey, S. O.; Maryanoff, B. E. *Tetrahedron Lett.* **1985**, *26*, 3915-3918.
8. (a) Hall, R. H.; Bischofberger, K.; Eitelmen, S. J.; Jordan, A. *J. Chem. Soc. Perkin Trans. 1*, **1977**, 743-753. (b) Baumberger, F.; Vasella, A; *Helv. Chim. Acta* **1983**, *66*, 2210-2222.
9. Holy, A.; *Collect. Czech. Chem. Commun.* **1989**, *54*, 446-454.
10. Tippie, M. A.; Martin, J. C.; Smee, D. F.; Matthews, T. R.; Verheyden, J. P. H. *Nucleosides Nucleotides* **1984**, *3*, 525-535.
11. Ti, G. S.; Gaffney, B. L.; Jones, R. A. *J. Am. Chem. Soc.* **1982**, *104*, 1316-1319.
12. (a) Jindrich, J. Holy, A.; Dvorakova, H. Collect. Czech. Chem. Commun. **1993**, 58, 1645-1667. (b) Pérez-Pérez, M.-J.; Rozenski, J.; Busson, R.; Herdewijn, P. *J. Org. Chem.* **1995**, *60*, 1531-1537.
13. Bronson, J. J.; Ghazzouli, I.; Hitchcock, M. J.; Webb, R. R.; Martin, J. C. *J. Med. Chem.* **1989**, *32*, 1457-1463.
14. Ashton, W.T.; Canning, M. L.; Cantone, C. L.; Field, A. K.; Hannah, J.; Karkas, J. D.; Liou, R.; Patel, G. F.; Perry, H. C.; Wagner, A. F.; Walton, E.; Tolman, R. L. *J. Med. Chem.* **1988**, *31*, 2304-2315.
15. Hossain, N.; Hendrix, C.; Lescrinier, E.; Van Aerschot, A.; Busson, R.; De Clercq, E.; Herdewijn, P. *Bioorg. Med. Chem. Lett.* (in preparation).

16. (a) Hossain, N.; Papchikhin, A.; Garg, N.; Fedorov, I.; Chattopadhyaya, J. *Nucleosides & Nucleotides* **1993**, *12*, 499-528 (b) Hossain, N.; Garg, N.; Chattopadhyaya, J. *Tetrahedron* **1993**, *49*, 10061-10068 (c) Garg, N.; Hossain, N.; Chattopadhyaya, J. *Tetrahedron* **1994**, *50*, 5273-5278.
17. Altomare, A.; Burla, M.C.; Camalli, M.; Cascarano, G.; Giacovazzo, C.; Guagliardi, A.; Polidori, G. *J. Appl. Cryst.* **1994**, *27*, 435-435.
18. Sheldrick, G. M. SHELXL93. Program for the Refinement of Crystal Structures. Univ. of Göttingen, Germany.
19. Zsolnai, L. ZORTEP -University of Heidelberg, Inorganic Chemistry, Germany.
20. Nardelli, M. *Comput. Chem.* **1983**, *7*, 95-98.

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