62. Facile Synthesis of 2'-Deoxyribofuranosides of Allopurinol and 4-Amino-1*H*-pyrazolo[3,4-*d*]pyrimidine *via* Phase-Transfer Glycosylation

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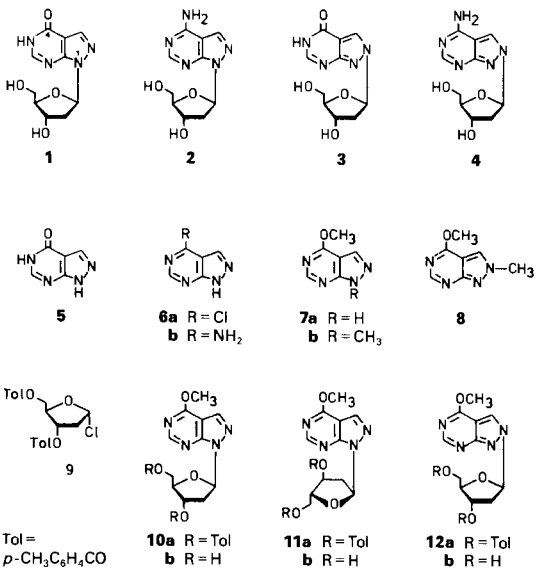
Phase-transfer glycosylation of 4-methoxy-1*H*-pyrazolo[3,4-*d*]pyrimidine with the 2-deoxyribofuranosyl chloride **9** formed the N(1)-β-nucleoside **10a** as main product (39%). As by-products the α-D-anomer **11a** (7%) and the N(2)-isomer **12a** (18%) were isolated. Assignment of these isomers was made on the basis of their ^{1}H- and ^{13}C-NMR spectra. Removal of the sugar-protecting groups yielded the 4-methoxy-nucleosides **10b**, **11b**, and **12b**, respectively. Nucleophilic displacement of the 4-MeO-group gave the 2-deoxyribofuranosides **1**–**4** of allopurinol and 4-amino-1*H*-pyrazolo[3,4-*d*]pyrimidine.

Modern strategies of oligonucleotide synthesis, in particular the use of phosphoramidites [1] and the application of polymeric matrices [2] allow the rapid preparation of oligonucleotides of defined sequences. This new methodology has recently been applied to rare or modified nucleosides [3] which, after incorporation into a DNA sequence, can alter biochemical or biophysical properties of the oligonucleotide. As an immediate consequence, efficient methods for the synthesis of modified 2'-deoxynucleosides have to be developed.

For the last few years, we have been dealing with the synthesis of pyrrolo[2,3-*d*]-pyrimidine nucleosides [4] which have then been enzymatically polymerized and which we are now incorporating into DNA sequences [5]. We now are extending our work to pyrazolo[3,4-*d*]pyrimidine nucleosides, in particular to the 2-deoxyribofuranosyl derivatives of allopurinol (**5**) and 4-amino-1*H*-pyrazolo[3,4-*d*]pyrimidine (**6b**). The allopurinol β-D-ribonucleoside is active against *Leishmania donovani* [6]. Enzymatic amination of allopurinol nucleoside leads to the β-D-ribofuranosyl derivative of **6b** [7] [8].

Previous to our work, the (2'-deoxyribofuranosyl) allopurinol **1** was unknown. The corresponding aminonucleoside **2** which is an isostere of 2'-deoxyadenosine is only available by enzymatic reactions using 2'-deoxyribosyltransferase from *Lactobacillus Leishmania* [9].

The glycosylation of allopurinol presents difficulties, due to nonregioselective reactions [10–12]. Recently, a regioselective synthesis of allopurinol ribonucleoside has been described starting with 4,6-dichloro-1*H*-pyrazolo[3,4-*d*]pyrimidine and employing trifluoromethanesulfonate as catalyst [13]. One disadvantage of this method as it was applied to ribonucleosides is that it is very long because of the transformation of the aglycon. We now report a facile synthesis of the 2'-deoxyribofuranosyl derivatives **1**–**4** using commercially available allopurinol (**5**) [14–16] as starting material.



Treatment of **5** with phosphorus trichloride oxide resulted in the formation of compound **6a** which is highly reactive at the 4-position. Even under conditions of ^{13}C-NMR experiments in Me_2SO solution (see below, *Table 1*) it was hydrolyzed to the starting material due to traces of H_2O. Nucleophilic displacement of the 4-halogen atom in **6a** by Na-methoxide furnished the 4-MeO derivative **7a**. According to other pyrazolo[3,4-*d*]-pyrimidines such as compound **6b**, it can be expected that also in **7a** a rapid proton transfer can occur between N(1) and N(2), whereby the system with the proton at N(1) should be the favoured tautomer [17].

Glycosylation of pyrrolo[2,3-*d*]pyrimidines with the 2-deoxyribofuranosyl chloride **9** has shown that electrophilic attack at N(7) of pyrrolo[2, 3-*d*]pyrimidines is favoured if the nucleobase anion is generated and phase-transfer conditions are employed. Therefore, it was concluded that regioselective alkylation [18] and glycosylation of compound **7a** could be achieved in a similar way. Phase-transfer glycosylation was carried out in a biphasic mixture of CH_2Cl_2 and 50% aq. NaOH solution. The organic layer contained the chromophor **7a**, the chloride **9**, and Bu_4NHSO_4 as catalyst. The glycosylation took place by thorough mixing with a vibromixer and was complete within a few minutes at room temperature. Preparative separation of the main and the two side products was accomplished by silica-gel column chromatography. The 3 compounds **10a**, **11a**, and **12a** were isolated in 39, 7, and 18% yield. Two of them, **10a** and **11a**, exhibited identical UV spectra with a main absorption maximum at 241 nm. The UV spectrum of **12a** was slightly different. All 3 compounds gave identical elemental analyses which agreed with the structure of a protected glycosylation product of **7a**.

Since the toluoyl groups masked the UV absorbance of the heterocylic base in **10a**, **11a**, and **12a**, they were split off by the action of NaOMe. After chromatographic purification, 3 crystalline products **10b**, **11b**, and **12b**, respectively, were obtained that again gave identical elemental analyses. The UV spectrum of **12b** was different from the one of **10b** and **11b**, but similar to that of the methylated chromophore **8** [18]; therefore it

Table 1. *^{13}C-NMR Chemical Shifts of Pyrazolo[3,4-d]pyrimidines and their 2'-Deoxyribofuranosyl Derivatives, in [D_6]Me_2SO*[a])

Compound	C(3)	C(3a)	C(4)	C(6)	C(7a)	CHO_3	C(1')	C(2')	C(3')	C(4')	C(5')	2 C(1")-*C*=O	2 C(1")	2 C(2"), 2 C(3"), 2 C(5"), 2 C(6")	2 C(4")	2 CH_3–C(4")
11a (α-D)	132.0	102.4	163.2	155.2	154.9	54.0	84.8	35.5	73.9	80.8	63.8	165.3	143.5	129.0	126.5	20.9
11b (α-D)	131.7	102.3	163.3	155.1	154.5	53.9	83.6	38.0	70.2	86.5	61.1					
10a (β-D)	132.3	102.4	163.3	155.3	154.9	54.0	84.3	35.2	74.6	81.3	63.7	165.1	143.5	129.0	126.4	20.9
10b (β-D)	131.9	102.4	163.3	155.2	154.5	54.0	84.2	38.0	70.9	87.6	62.2					
1 (β-D)	134.9	106.2	156.8	148.1	152.3		84.0	38.1	70.9	87.7	62.3					
2 (β-D)	132.8	100.4	157.3	155.7	153.6		84.1	38.0	71.0	87.5	62.3					
12a (β-D)	124.3	102.2	[b])	155.2	160.8	53.7	90.6	37.0	74.4	82.3	63.7	165.1	143.5	129.0	126.3	20.8
12b (β-D)	123.1	102.0	164.9	154.9	160.6	53.9	90.9	40.5	69.9	88.4	61.3					
3 (β-D)	127.5	106.8	158.3	146.8	158.6		90.3	40.5	70.1	88.2	61.5					
4 (β-D)	123.6	101.3	159.4	156.6	159.5		90.5	40.3	70.6	88.3	62.0					
5	134.1	105.6	157.4	147.5	154.4											
6a	132.5	112.5	154.5	154.5	153.5											
6b	132.3	99.5	157.9	155.6	154.8											
7a	131.1	101.2	163.2	154.6	156.1	53.6										

[a]) δ Values given in ppm relative to Me_4Si as internal standard.

[b]) Masked by C(1")–*C*=O.

was concluded that its structure is represented by *Formula* **12b**. The glycosylation site in **12b** was confirmed by the regular and the $^{13}C/^{1}H$-coupled ^{13}C-NMR spectra *(Tables 1* and *2)* and its anomeric configuration determined by the ^{1}H-NMR data of **12a**.

Compared to the chromophore **7a, 12b** exhibits a strong upfield shift in the ^{13}C-NMR for the C(3) signal, which is located at a position close to that of the methyl compound **8** [18]. Unambiguous information about the glycosylation position came from the $J_{C,H}$ of **12b** *(Table 2)*. Besides the coupling with H–C(3) (^{1}J = 198.6 Hz), the C(3) signal exhibits an additional coupling (^{3}J = 2.1 Hz) with the anomeric proton which is not observed with the other glycosylation products. It has been already observed by *Nuhn et al.* [19] for regular 2'-deoxynucleosides and found by us for pyrrolo[2,3-*d*]pyrimidine 2'-deoxynucleosides that the ^{1}H-NMR signals of H–C(4') and 2H–C(5') are well separated in the series of the α-D-anomers but coincide for the β-D-compounds. As *Table 3* shows, H–C(4') and 2H–C(5') of **12a** appear at almost the same chemical shift indicating β-D-configuration.

Table 2. $J_{C,H}$ *Values* [Hz] of *(2-Deoxyribofuranosyl)pyrazolo[3,4-*d*]pyrimidines*[a])

$J_{C,H}$	**11b**	**10b**	**1**	**2**	**12b**	**3**	**4**
C(3),H–C(3)	196.7	196.5	192.2	193.0	198.6	195.2	195.1
C(3),H–C(1')					2.1	2.1	1.8
C(3a),H–C(3)	10.4	10.5	9.9	10.4	7.8	7.6	7.4
C(4),H–C(6)	[b])	11.0	6.9	11.1	[b])	6.7	10.6
C(4),CH_3O		4.2					
C(6),H–C(6)	205.8	205.6	205.8	196.5	203.5	204.5	195.6
C(7a),H–C(1')	[b])	[b])	1.8	1.7			
C(7a),H–C(3)			4.6	3.4	7.9	7.3	12.2
C(7a),H–C(6)			13.2	11.3	12.6	14.1	12.2
C(1'),H–C(1')	165.3	165.4	162.9	164.8	168.5	168.5	169.1
C(3'),H–C(3')	147.3	148.8	151.0	150.4	151.5	148.9	149.0
C(4'),H–C(4')	148.3	147.1	147.0	146.9	147.3	147.3	147.9
C(5'),H–C(5')	139.2	139.6	139.6	139.1	138.1	139.9	141.0

[a]) Data taken from ^{13}C-NMR spectra measured in $[D_6]Me_2SO$.
[b]) Not resolved.

From the identical UV data (λ_{max} 247 nm) of **10b** and **11b** it was concluded that these compounds are anomers. This is underlined by the ^{13}C-NMR data for their chromophore moieties which are almost identical and also very similar to those of compound**7a** *(Table 1)*. The assignment of the anomeric configuration of **10b** and **11b** cannot be made on the basis of the ^{13}C-NMR chemical shifts of the sugar moieties (see [20]); it was given by the ^{1}H-NMR data of **10a** and **11a**, respectively, indicating β-D-configuration for the major (39%) glycosylation product **10a** and hence for **10b** (see *Table 3* and discussion of the ^{1}H-NMR data of **12a** above).

It can be concluded that the phase-transfer glycosylation is an efficient method to obtain the β-D-nucleoside **10a** in good yield from easily accessible starting materials. The α-D-anomer **11a,** which is formed in about equal amounts by other glycosylation procedures using the 2'-deoxyribofuranosyl chloride **9,** is a minor product (7%) of the phase-transfer glycosylation. Unfortunately, the N(2)-glycosylation product **12a** is also formed to some extent, but other glycosylation products were not detected. The conversion of the 4-methoxynucleosides **10b** and **12b** into the allopurinol nucleosides **1** and **3,** respectively, without cleaving the N-glycosylic bond was difficult. Cleavage of the MeO-group with acid resulted in hydrolysis of the N-glycosylic bond. However, earlier findings on the methylated chromophores **7b** or **8** [18] have shown that the 4-MeO-group can be con-

Table 3. *^{1}H-NMR Chemical Shifts of (2-Deoxyribofuranosyl)pyrazolo[3,4-d]pyrimidine in [D_6] Me_2SO*[a])

Compound	H–C(3)	H–C(6)	CH_3O- or NH_2–C(4)/ H–N(5)	H–C(1′)	H_a–C(2′)	H_b–C(2′)	H–C(3′)	OH–C(3′)	H–C(4′)	2 H–C(5′)	OH–C(5′)	2 C_6H_4	2 CH_3
11a (α-D)	8.34 (*s*)	8.61 (*s*)	4.10 (*s*, 3H)	6.84 (*dd*, *J* = 4.4, 7.4)	3.22 (*q*, *J* = 7.7)	2.99 (*d't'*, *J* = 4.6, 14.2)	5.58 (*ddd*[b]))	–	4.74 (*dt*, *J* = 4.5, 4.7)	4.51 (*dAB*[b]))		7.30, 7.87 (4*d*, J = 8.1, 8.2)	2.36 (2*s*)
11b (α-D)	8.37 (*s*)	8.65 (*s*)	4.12 (*s*, 3H)	6.60 (*'t'*, *J* = 6.5)	2.78 (*'quint'*, *J* = 6.9)	2.67 (*'quint.'*, *J* = 6.9)	4.16 (*'quint.'*, *J* = 6.8)	5.47 (*d*, *J* = 6.7)	3.96 (*dt*[b]))	3.41, 3.57 (*ddAB*[b]))	4.74 (*t*, *J* = 5.7)		
10a (β-D)	8.37 (*s*)	8.64 (*s*)	4.11 (*s*, 3H)	6.87 (*'t'*, *J* = 6.0)	3.30 (*ddd*[b]))	2.81 (*ddd*[b]))	5.87 (*ddd*[b]))	–	4.48 (*dt*[b])) + 4.48 (*dAB*[b]))			7.33, 7.89 (4*d*, *J* = 8.0)	2.39 (2*s*)
10b (β-D)	8.32 (*s*)	8.63 (*s*)	4.11 (*s*, 3H)	6.67 (*'t'*, *J* = 6.4)	2.84 (*'quint'*, *J* = 6.4)	2.31 (*ddd*, *J* = 4.4, 6.8, 13.1)	4.46 (*dddd*[b])	5.31 (*d*, *J* = 4.6)	3.83 (*dt*, *J* = 3.6, 5.8)	3.36, 3.52 (*ddAB*[b]))	4.72 (*t*, *J* = 5.7)		
1 (β-D)	8.14 (*s*) / 8,17 (*s*)		12.22 (*s*, 1H)	6.52 (*'t'*, *J* = 6.6)	2.76 (*'quint.'*, *J* = 6.3)	2.26 (*ddd*, *J* = 4.5, 6.8, 13.1)	4.43 (*dddd*[b])	5.30 (*'d'*)	3.81 (*dt*, *J* = 3.6, 5.8)	3.30, 3.50 (*ddAB*[b]))	4.74 (*t*[b]))		
2 (β-D)	8.14 (*s*) / 8.18 (*s*)		7.72 (*s*, 2H)	6.54 (*'t'*, *J* = 6.5)	2.80 (*'quint.'*, *J* = 6.4)	2.23(*ddd*, *J* = 4.0, 6.6, 13.2)	4.43 (*dddd*[b]))	5.24 (*d*, *J* = 4.5)	3.81 (*dt*, *J* = 3.3, 5.5)	3.37, 3.52 (*ddAB*[b]))	4.80 (*t*, *J* = 5.7)		
12a (β-D)	8.59 (*s*) / 8.83 (*s*)		4.05 (*s*, 3H)	6.64 (*'t'*, *J* = 5.6)	3.20 (*'quint.'*, *J* = 5.4)	2.90 (*'quint.'*, *J* = 5.1)	5.85 (*ddd*[b]))	–	4.57 (*dt*[b])) + 4.57 (*dAB*[b]))			7.38, 7.86 (4*d*, *J* = 8.1)	2.36 (2*s*)
12b (β-D)	8.56 (*s*) / 8.87 (*s*)		4.08 (*s* 3H)	6.36 (*'t'*, *J* = 5.8)	2.62 (*'quint.'*, *J* = 6.3)	2.41 (*'quint.'*, *J* = 6.3)	4.40 (*dddd*[b]))	5.34 (*d*, *J* = 4.4)	3.92 (*dt*[b]))	3.51, 3.63 (*ddAB*[b]))	4.96 (*t*, *J* = 5.3)		
3 (β-D)	8.00 (*s*)	8.74 (*s*)	11.75 (*s*, 1H)	6.22 (*'t'*, *J* = 5.9)	2.59 (*'quint.'*, *J* = 6.0)	2.33 (*'quint.'*, *J* = 6.1)	4.38 (*dddd*[b]))	5.31 (*d*, *J* = 4.3)	3.87 (*dt*, *J* = 4.2, 4.5)	3.53 (*ddAB*[b]))	4.93 (*t*, *J* = 5.9)		
4 (β-D)	8.14 (*s*) / 8.50 (*s*)		7.67 (*s*, 2H)	6.31 (*'t'*, *J* = 5.9)	2.62 (*'quint.'*, *J* = 6.1)	2.36 (*'quint.'*, *J* = 6.2)	4.37 (*dddd*[b]))	5.33 (*d*, *J* = 4.3)	3.91 (*dt*, *J* = 4.0, 5.0)	3.53 (*ddAB*[b]))	4.90 (*t*, *J* = 5.5)		

[a]) δ Values given in ppm relative to Me_4Si as internal standard. Coupling constants *J* in Hz. Splitting patter: *s*, singulet; *d*, doublet; *t*, triplet; *'t'*, pseudotriplet; *AB*, *AB 'quadruplet'*; *'quint.'*, pseudoquintuplet.

[b]) Splitting pattern not resolved.

verted into an OH-group by storing these compounds in dilute NaOH solution. Applying these conditions of nucleophilic displacement to **10b** and **12b** converted them within 2 h, into the crystalline allopurinol nucleosides **1** and **3,** respectively, without formation of any side product. This was confirmed by the ^{1}H- and ^{13}C-NMR spectra of **1** and **3** *(Tables 1–3)*.

TLC monitoring showed the reaction to be more rapid in the case of **12b** than in the case of **10b.** In order to quantify the nucleophilic displacement, it was followed spectrophotometrically in 1N NaOH/MeOH 1:1. From the change of the UV absorption (**10b** at 270 nm; **12b** at 260 nm) the half-life at 25°C was calculated and found to be 123 min for **10b** and 37 min for **12b.** An increase of the NaOH concentration (2N NaOH/MeOH 1:1) did not affect the kinetics of the N(2)-nucleoside **12b,** whereas the half-life of the N(1)-isomer was now 69 min.

Replacing the aq. NaOH solution by conc. aq. ammonia compounds **10b** and **12b** were converted into the crystalline amino nucleosides **2** and **4,** respectively, within 3 days at room temperature. Only traces of the corresponding allopurinol nucleosides **1** and **3** could be detected under these conditions. The ^{1}H- and ^{13}C-NMR data of **1–4** *(Tables 1–3)* were in agreement with their structures. Moreover, the synthetic nucleoside **2** was identical in its spectroscopic and chromatographic properties to an authentical sample of **2** obtained by enzymatic preparation [12].

In the ^{13}C-NMR spectra of nucleosides, the $^1J_{C,H}$ coupling constants allow a rapid identification of the anomeric C-atom among all other sugar signals due to the fact that $^1J_{C(1'),H-C(1')}$ exhibits values around 165 Hz, whereas the other $^1J_{C,H}$ of the sugar moiety are definitely smaller (140–150 Hz) [21]. Applying these findings to the analysis of the spectra of the N(1)-nucleosides **1, 2, 10b,** or **11b,** the sequence of the chemical shifts of the sugar C-atoms is found to be the same (C(4'), C(1'), C(3'), C(5'), C(2')) as for purine or pyrrolo[2,3-*d*]pyrimidine 2'-deoxynucleosides. In contrast, the sequence of the sugar signals of the N(2)-nucleosides **3, 4,** and **12b** is different. As can be seen from the coupling pattern *(Table 2)* the low-field signal of the sugar moieties shows the largest coupling constant (*ca.* 170 Hz). Therefore the sequence of the sugar signals is C(1'), C(4'), C(3'), C(5'), C(2'). Hence, only the chemical shifts of C(1') and C(2') differ between N(1)- and N(2)-nucleosides, whereas the δ's of C(3'), C(4'), and C(5') are almost unaffected.

The facile synthesis of the nucleosides **1** and **2** implies that phase-transfer glycosylation could also be applicable to other pyrazolo[3,4-*d*]pyrimidine nucleosides of biological interest. Investigations towards the synthesis of such nucleosides are in progress.

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Note Added in Proof. – Compound **2** has recently been described by Z. Kazimierczuk, H. B. Cottam, G. R. Revankar, R. K. Robins, *J. Am. Chem.* Soc. **1984,** *106,* 6379.

Experimental Part

General. M.p.s were determined on a *Linström* apparatus (*Wagner & Munz,* W.-Germany) and are not corrected. UV spectra (λmax(ε) in nm) were measured on a *Uvikon 810* spectrometer (*Kontron,* Switzerland); NMR spectra were recorded on a *Bruker WM 250* spectrometer, δ's are relative to Me_4Si as internal standard for ^{1}H and ^{13}C. Elemental analyses were performed by *Mikroanalytisches Labor Beller* (Göttingen, W.-Germany). TLC was carried out on silica gel *SIL G-25 UV$_{254}$* plates (*Macherey-Nagel & Co.,* Düren, W.-Germany). Silica gel *60* (230–400 mesh ASTM; *Merck,* Darmstadt, W.-Germany), *Amberlite-XAD-4 resin* (*Serva,* Heidelberg, W.-Germany), and *Dowex 1 × 2* ion-exchange resin (OH^- form, *Serva,* Heidelberg, W.-Germany) were used for column chromatography. The columns were connected to an *Uvicord-S* detector and an *UltroRac* fraction collector (*LKB Instruments,* Bromma, Sweden). Chromatography was performed with solvent systems CH_2Cl_2 (A), CH_2Cl_2/AcOEt 95:5 (B), CH_2Cl_2/AcOEt 9:1 (C), cyclohexane/AcOEt 4:1 (D), $CHCl_3$/MeOH 95:5 (E), $CHCl_3$/MeOH 9:1 (F), and $CHCl_3$/MeOH 4:1 (G). Allopurinol (**5**) was purchased from *Sigma Chemical Co.* (St. Louis, USA).

*Phase-Transfer Glycosylation of 4-Methoxy-1*H*-pyrazolo[3,4-*d*]pyrimidine* (**7a**) *with 2-Deoxy-3,5-di-*O*-(*p*-toluoyl)-α-*D*-erythro-pentofuranosyl Chloride* (**9**). A suspension of **7a** [6] [14] (514 mg, 3.4 mmol) and Bu_4NHSO_4 (122 mg, 0.36 mmol) in CH_2Cl_2 (20 ml) and an equal volume of 50% aq. NaOH soln. was stirred with a vibromixer at r.t. The chloride **9** [22] (1.47 g, 3.8 mmol) in CH_2Cl_2 (17 ml) was dropped into the emulsion within 2 min and mixing was continued for 1 min. Thereupon the org. layer was separated and the aq. layer extracted 3× with CH_2Cl_2 (50 ml). The org. layers were combined, dried over Na_2SO_4, filtered, and evaporated to dryness. The oily residue was dissolved in CH_2Cl_2 and chromatographed on a silica-gel column (20 × 4 cm). From the fast migrating main zone (eluant A), colorless *1-[2-deoxy-3,5-di-*O*-(*p*-toluoyl)-β-*D*-erythro-pentofuranosyl]-4-methoxy-1*H*-pyrazolo[3,4-*d*]pyrimidine* (**10a**) was isolated (673 mg, 39%). Crystallization from i-PrOH yielded colorless needles, m.p. 95–98° (sintering at 70°). TLC(D): R_f 0.6 UV (MeOH): 241 (36400). Anal. calc. for $C_{27}H_{26}N_4O_6$: C 64.53, H 5.22, N 11.15; found: C 64.67, H 5.40, N 11.18.

From the second zone (eluted partially with A then with B) colorless amorphous *1-[2-deoxy-3,5-di-*O*-(*p*-toluoyl)-α-*D*-erythro-pentofuranosyl]-4-methoxy-1*H*-pyrazolo[3,4-*d*]pyrimidine* (**11a**; 120 mg, 7.0%) was obtained. TLC(D): R_f 0.55. UV (MeOH): 241 (38700). Anal. calc. for $C_{27}H_{26}N_4O_6$: C 64.53, H 5.22, N 11.15; found: C 64.44, H 5.34, N 11.01.

The slow migrating zone (eluted with C) yielded colorless foamy *2-[2-deoxy-3,5-di-*O*-(*p*-toluoyl)-β-*D*-erythro-pentofuranosyl]-4-methoxy-2*H*-pyrazolo[3,4-*d*]pyrimidine* (**12a**; 304 mg, 17.7%) upon evaporation. Crystallization from i-PrOH led to colorless crystals of m.p. 162–164°. TLC(D): R_f 0.2. UV (MeOH): 242 (36000). Anal. calc. for $C_{27}H_{26}N_4O_6$: C 64.53, H 5.22, N 11.15; found: C 64.70, H 5.36, N 11.16.

*1-(2-Deoxy-β-*D*-erythro-pentofuranosyl)-4-methoxy-1*H*-pyrazolo[3,4-*d*]pyrimidine* (**10b**). A soln. of **10a** (1.31 g, 2.61 mmol) in 0.1M NaOMe/MeOH (70 ml) was stirred for 4 h at r.t. Then the soln. was adsorbed onto silica gel (13 g) and chromatographed on a silica-gel column (10 × 5 cm). Elution with E resulted in a main zone which yielded a colorless solid. Crystallization from H_2O gave **10b** as colorless needles (555 mg, 80%) with m.p. 176°. TLC(F): R_f 0.6. UV (MeOH): 247 (7700), 263 (sh, 4700). Anal. calc. for $C_{11}H_{14}N_4O_4$: C 49.62, H 5.30, N 21.04; found: C 49.76, H 5.34, N 21.14.

*1-(2-Deoxy-α-*D*-erythro-pentofuranosyl)-4-methoxy-1*H*-pyrazolo[3,4-*d*]pyrimidine* (**11b**). A soln. of **11a** (240 mg, 0.48 mmol) in 0.1M NaOMe/MeOH (15 ml) was treated as **10a** above. After chromatography, colorless amorphous **11b** was isolated which crystallized from H_2O as colorless plates (88 mg, 69%) with m.p. 150–152°. TLC(F): R_f 0.63. UV (MeOH): 247 (7900), 263 (sh, 4700). Anal. calc. for $C_{11}H_{14}N_4O_4$: C 49.62, H 5.30, N 21.04; found: C 49.45, H 5.39, N 21.10.

*2-(2-Deoxy-β-*D*-erythro-pentofuranosyl)-4-methoxy-2*H*-pyrazolo[3,4-*d*]pyrimidine* (**12b**). Treatment of **12a** (1.06 g, 2.11 mmol) in 0.1 M NaOMe/MeOH (60 ml) as described for **10b** gave colorless foamy **12b** after chromatography (F). Crystallization from H_2O yielded colorless needles (427 mg, 76%) with m.p. 180–181°. TLC(G): R_f 0.46. UV (MeOH): 260 (9600). Anal. calc. for $C_{11}H_{14}N_4O_4$: C 49.62, H 5.30, N 21.04; found: C 49.76, 5.38, N 21.08.

*1-(2-Deoxy-β-*D*-erythro-pentofuranosyl)-1*H*-pyrazolo[3,4-*d*]pyrimidin-4(5*H*)-one(= (2'-Deoxyribofuranosyl)allopurinol,* **1**). A soln. of **10b** (505 mg, 1.9 mmol) in 2N aq. NaOH (50 ml) was stirred for 2 h at r.t. The soln. was neutralized with an aliquot of 2N HCl and then applied to an *Amberlite-XAD-4* column (20 × 2 cm). Inorg. salt was removed by washing with H_2O, **1** was eluted with H_2O/i-PrOH 9:1 (*v/v*). Crystallization from i-PrOH yielded **1** as colorless needles (406 mg, 85%) with m.p. 202–203° [23]. TLC(F): R_f 0.2. UV (MeOH): 251 (7500). Anal. calc. for $C_{10}H_{12}N_4O_4$: C 47.62, H 4.80, N 22.21; found: C 47.76, H 4.91, N 22.18.

*2-(2-Deoxy-β-*D*-erythro-pentofuranosyl)-2*H*-pyrazolo[3,4-*d*]pyrimidin-4(5*H*)-one* (**3**). A soln. of **12b** (261 mg, 0.98 mmol) in 2M aq. NaOH (25 ml) was treated as described for **10b.** After chromatographic separation on an *Amberlite-XAD-4* column (20 × 2 cm), the residue of the main zone was crystallized from H_2O to yield colorless crystals of **3** as a hydrate. This became amorphous by drying at 120° *in vacuo* (196 mg, 79%). TLC(G): R_f 0.42. UV (MeOH): 261 (9100), 264 (9100). Anal. calc. for $C_{10}H_{12}N_4O_4$: C 47.62, H 4.80, N 22.21; found: C 47.70, H 4.84, N 22.41.

*4-Amino-1-(2-deoxy-β-*D*-erythro-pentofuranosyl)-1*H*-pyrazolo[3,4-*d*]pyrimidine* (**2**). A soln. of **10b** (333 mg, 1.25 mmol) in conc. aq. NH_3 (200 ml) was stored at r.t. for 3 days. The solv. was evaporated and the residue crystallized from i-PrOH yielding **2** as colorless crystals (268 mg, 85%) with m.p. 245–246° [12]. TLC(G): R_f 0.42. UV (MeOH): 260 (9500), 275 (10900). Anal. calc. for $C_{10}H_{13}N_5O_3$: C 47.81, H 5.22, N 27.88; found: C 47.62, H 5.34, N 27.98.

*4-Amino-2-(2-deoxy-β-*D*-erythro-pentofuranosyl)-2*H*-pyrazolo[3,4-*d*]pyrimidine* (**4**). A soln. of **12b** (354 mg, 1.33 mmol) in conc. NH_3 (100 ml) was stirred at r.t. for 3 days, then the solv. evaporated, the residue dissolved in H_2O (50 ml), and the soln. adsorbed onto a *Dowex 1 × 2* ion-exchange column (15 × 2 cm, OH^- form). Elution with MeOH/H_2O 3:2 to H_2O (600 ml, each; linear gradient) afforded a main zone from which **4** was obtained.

Recrystallization from EtOH/pentane yielded colorless crystals (228 mg, 68%) with m.p. 197–200°. TLC(G): R_f 0.17. UV (MeOH): 231 (7400), 260 (6800), 268 (7700), 292 (10200). Anal. calc. for $C_{10}H_{13}N_5O_3$: C 47.81, H 5.22, N 27.88; found: C 47.97, H 5.18, N 27.83.

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