Te–C angle, 87.62 (14)°, is considerably smaller than that found in the unconstrained Ph_2Te_2 molecule (98.9 (15)°).[25]

Acknowledgment. The work at Brandeis University was supported in part by the Office of Naval Research. We thank D. Dugger, F. X. Pink, and M. A. McGrath for providing mass spectral, ESCA, and diffuse reflectance data, respectively, G. D. Zoski for the use of electrochemical apparatus and helpful discussions, W. A. Burke and S. Meyler for general technical assistance, and Joanne McLaughlin for typing the manuscript.

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Supplementary Material Available: Tables of (i) experimental data, (ii) atomic coordinates, (iii) anisotropic thermal parameters, (iv) bond lengths and angles, and (v) observed and calculated structure factors (10 pages). Ordering information is given on any current masthead page.

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Palladium-Catalyzed Reactions of Glycals with (1,3-Dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl)mercuric Acetate. Facile Regio- and Stereospecific *C*-Nucleoside Syntheses

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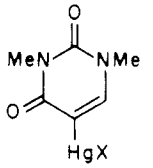
Received September 9, 1981

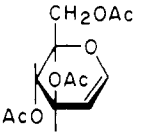
Reactions of the glycals, 3,4,6-tri-*O*-acetyl-D-glucal, 3,4-di-*O*-acetyl-D-arabinal, and 3,4-di-*O*-acetyl-D-xylal, with (1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl)mercuric acetate in the presence of a stoichiometric quantity of $Li_2Pd(OAc)_2Cl_2$ resulted in regio- and stereospecific carbon–carbon bond formation between C-5 of the pyrimidine moiety and C-1 of the carbohydrate. Regiospecificity in this reaction results from the dipolar nature of the enol ether double bond; stereospecificity derives from exclusive approach of the metallopyrimidine reagent to the face of the carbohydrate (enol ether) opposite that bearing the allylic acetate group.

In a preliminary report,[2] we described palladium-catalyzed reactions of glycals, 1,2-unsaturated carbohydrates, with a pyrimidin-5-ylmercuric salt which result in regiospecific carbon-carbon bond formation between C-5 of the pyrimidine moiety and C-1 of the carbohydrate. This reaction constitutes a new, facile *C*-nucleoside[3] synthesis. We have also reported related studies involving palladium-catalyzed reactions of other enol ethers and acetates.[4-6] Recently Czernecki and Gruy[7] have reported related palladium-catalyzed glycal arylation reactions.[8]

In the present report we (a) describe further studies of the palladium-catalyzed reactions of glycals which we have found to be sensitive to the nature of the anions present in the reaction mixture,[9] (b) discuss mechanistic aspects of the addition reaction (which determines product regio- and stereochemistry) and of adduct decomposition reactions (which give rise to three discrete *C*-nucleoside products),[10] (c) discuss the chromatographic and spectrometric properties of these product *C*-nucleosides, and (d) describe cyclization of an acyclic *C*-nucleoside produced in the primary reaction.



1



2

Regio- and Stereospecific Reactions of a Pyrimidinylpalladium Reagent with Glycals. Reaction of (1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl)mercuric acetate[4] (1, X = OAc) with 3,4,6-tri-*O*-acetyl-D-glucal[11] (2) in acetonitrile in the presence of a stoichiometric quantity of the palladium(II) salt $Li_2Pd(OAc)_2Cl_2$ afforded one major product, (*Z*)-1,2-dideoxy-1-(1,2,3,4-tetrahydro-1,3-dimethyl-2,4-dioxo-5-pyrimidinyl)-D-*arabino*-hex-1-enitol 3,4,6-triacetate (3) and two minor ones, 5-(4,6-di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranosyl)-1,3-

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(2) Arai, I.; Daves, G. D., Jr. *J. Am. Chem. Soc.* **1978**, *100*, 287.

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(4) Arai, I.; Daves, G. D., Jr. *J. Org. Chem.* **1978**, *43*, 4110.

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(8) Palladium-catalyzed allylic substitution of alkyl hex-2-enopyranosides has also been accomplished. See: Baer, H. H.; Hanna, Z. S. *Can. J. Chem.* **1981**, *59*, 889; *Carbohydr. Res.* **1981**, *94*, 43.

(9) Another anion-sensitive palladium-catalyzed reaction has also been reported: Arai, I.; Hanna, R.; Daves, G. D., Jr. *J. Am. Chem. Soc.* **1981**, *103*, 7684.

(10) See also: Arai, I.; Daves, G. D., Jr. *J. Am. Chem. Soc.* **1981**, *103*, 7683.

(11) Roth, W.; Pigman, W. In "Methods in Carbohydrate Chemistry"; Academic Press: New York, 1963; Vol. II, p 405.

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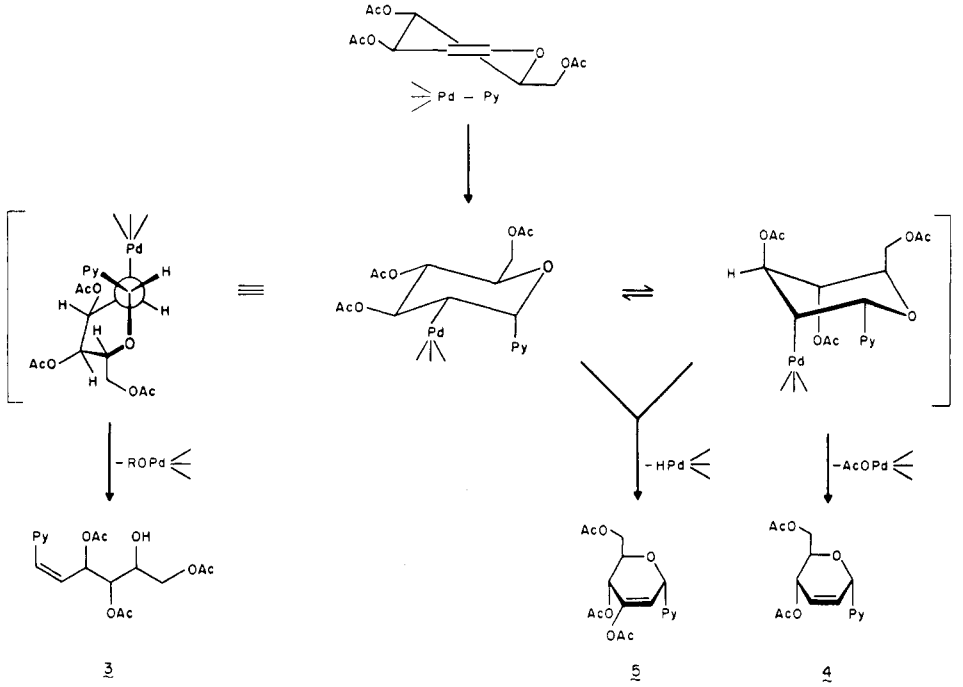
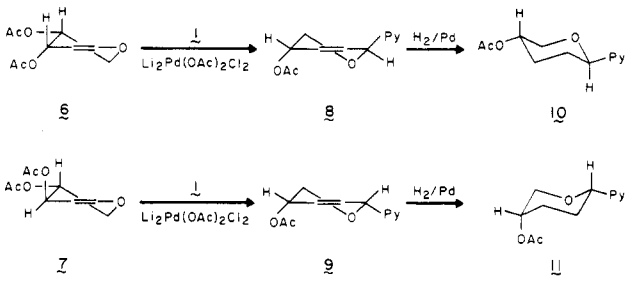
Scheme I. Palladium-Catalyzed Reaction of 3,4,6-Tri-*O*-acetyl-D-glucal (2) with 3,4-Dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl (Py) Mercuric Acetate (1, X = OAc)



dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (**4**) and 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-deoxy-α-D-*erythro*-hex-2-enopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**5**).[2,12]

These results indicate that adduct formation between the pyrimidinylpalladium species and the glycal is both regio- and stereospecific. Consideration of these and other results[4-6] and the known stereochemistries of other palladium-mediated addition and elimination processes[13,14] leads us to formulate the reactions as shown in Scheme I.[10] Approach of the pyrimidin-5-yl (Py) palladium complex, formed in situ, is to the face of the cyclic enol ether (which probably exists largely in a half-chair conformation as depicted[15-17]) opposite that bearing the allylic acetoxy group.[2] The result is regio- and stereospecific syn addition of the pyrimidin-5-ylpalladium complex to the enol ether double bond to form a single σ-bonded palladium adduct.[10] Under the reaction conditions, this unstable palladium adduct decomposes via three distinct processes; i.e., by (a) anti elimination with alkoxide expulsion,[18-22] ring cleavage and formation of a *Z* olefinic bond in the resulting acyclic carbohydrate moiety of **3**, (b) antielimination of acetoxy[13,23,24] and palladium to form **4**, and (c) syn elimination

Scheme II. Stereospecific Addition of PyHgOAc (1, X = OAc) to 3,4-Di-*O*-acetyl-D-arabinal (6) and 3,4-Di-*O*-acetyl-D-xylal (7)



of a hydridopalladium species to form enol acetate **5**.[12] As noted in our preliminary report[2] and shown in Scheme I, decomposition of the initial enol ether–organopalladium adduct is constrained by conformational (as well as steric[13,14]) factors.

Independent evidence for the regio- and stereospecific nature of adduct formation and the pivotal role of the C-3 allylic acetoxy group[2] was provided by study of the palladium-catalyzed reactions of (1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl)mercuric acetate (**1**, X = OAc) with 3,4-di-*O*-acetyl-D-arabinal[25] (**6**) and 3,4-di-*O*-acetyl-D-xylal[26] (**7**), which are isomers enantiomeric at the site of the allylic acetate function (C-3). Reaction of **1** with **6** and **7** yielded, in each instance, a product mixture which contained a single monoacetoxy *C*-nucleoside (Scheme II). Catalytic reductions of these isomeric monoacetoxy *C*-nucleosides (**8** and **9**), afforded the tetrahydropyranyl isomers **10** and **11**. That the assigned stereochemistries of isomers **10** and **11** are correct is evident by examination of their ^{1}H nuclear magnetic resonance (^{1}H NMR) spectra. The H-1 (anomeric H) resonance in each spectrum appears as a broad[27]

(12) In our preliminary report[2] compound **5** was not identified.
(13) For general reviews of organopalladium chemistry see Henry, P. M. *Adv. Organomet. Chem.* **1975**, *13*, 363. Trost, B. M. *Tetrahedron* **1977**, *33*, 2615. Heck, R. F. "Organotransition Metal Chemistry"; Academic Press: New York, 1974. Maitlis, P. M. "The Organic Chemistry of Palladium"; Academic Press: New York, 1971; Vols. I and II. Tsuji, J. "Organic Synthesis with Palladium Compounds"; Springer-Verlag: Berlin, 1980.
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(25) Humoller, F. L. In "Methods in Carbohydrate Chemistry"; Academic Press: New York, 1962; Vol. I, p 83.
(26) Weygand, F. In "Methods in Carbohydrate Chemistry"; Academic Press: New York, 1962; Vol. 1, p 182.

Table I. Influence of Anions (Cl^-, OAc^-) on the Li_2PdX_4-Catalyzed Reaction of (1,3-Dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl)mercuric Salts (1) with 3,4,6-Tri-*O*-acetyl-D-glucal (2)

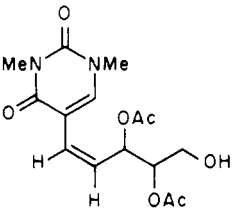
ratio Cl^-:OAc^-	product yields[a] 3	4	5
5:0	0	0	0
3:2	37-40	0	0
2:3	60-73	~10	~10
0:5	0	~40	~40

[a] For reaction conditions see Experimental. Yields (%) are of product isolated following chromatography of the reaction mixture over silica gel; yields of 4 and 5 are based on HPLC analysis of a mixture obtained by silica gel column chromatography.

doublet, J = 10 Hz, indicative of an axial hydrogen;[28] i.e. in each isomer the bulky pyrimidinyl moiety occupies an equatorial position on the tetrahydropyranyl ring. The H-4 resonance of **10** appears as a complex multiplet with $J_{4,3a,e} + J_{4,5a,e}$ = 36 Hz (width of multiplet measured at base line) establishing this hydrogen as axial and the structure of **10** as (2*R-trans*)-5-[5-(acetyloxy)-5,6-dihydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (Scheme II). Similarly, in the spectrum of **11** H-4 appears as a broad resonance, $J_{4,5a,e} + J_{4,3a,e}$ = 14 Hz, indicative of an equatorial hydrogen and establishes **11** as (2*S-cis*)-5-[5-(acetyloxy)-5,6-dihydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4-(1*H*,3*H*)-pyrimidinedione (Scheme II). In each case, the stereochemistry is that predicted by adduct formation via syn addition of the pyrimidinylpalladium complex to the face of the cyclic enol ether opposite that occupied by the allylic acetate function at C-3 as depicted in Scheme I.[2]

Effect of Change in Anion Ratios on Adduct Formation and Decomposition Reactions. The ionic content of the reaction medium influences both the initial adduct formation and the subsequent adduct decomposition processes (Table I).[9] If only chloride salts (i.e., PyHgCl, $PdCl_2$, LiCl) are used, the pyrimidinylpalladium glycal adduct (Scheme I) is not formed. If the Cl^-:OAc^- ratio is adjusted to 3:2 (by employing $Pd(OAc)_2$) adduct formation occurs and a moderate yield of acyclic nucleoside **3** is produced. Increase of the relative concentration of acetate to 2:3 Cl^-:AcO^- results in a significant increase in the yield of **3** but, under these conditions, low yields of **4** and **5** are also produced. Finally if only acetate anions are present, adduct formation occurs but **3** is not formed and the cyclic carbohydrate products **4** and **5** now account for the bulk of the reactants consumed. Several effects are evident: (a) high chloride content inhibits the pyrimidinylpalladium–glycal adduct formation, (b) use of acetate anions permits high yield adduct formation, (c) the carbohydrate ring-opening reaction with formation of acyclic product **3** occurs in the presence of chloride ion and, conversely, in the absence of chloride ion adduct decomposition occurs with formation of cyclic products **4** and **5**, and (d) selection between the decomposition pathways leading to **4** and **5** exhibits little sensitivity to these changes in the anionic contents of the reaction mixtures.[10]

Other Products of Reaction of 3,4-Di-*O*-acetyl-D-glycal (6) and -xylal (7) with 1. In the reaction of 3,4-di-*O*-acetyl-D-arabinal[25] (**6**) with **1** (Scheme II), in addition to the acetoxydihydropyranyl *C*-nucleoside **8**, (*Z*)-1,2-dideoxy-1-(1,2,3,4-tetrahydro-1,3-dimethyl-2,4-dioxo-5-pyrimidinyl)-D-*erythro*-pent-1-enitol 3,4-diacetate[2] (**12**) was formed in comparable yield. Similarly, reaction of **1** with 3,4-di-*O*-acetyl-D-xylal[25] (**7**) produced, in addition to **9** (Scheme II), (2*S-cis*)-5-[4,5-bis(acetyloxy)-5,6-dihydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (**13**). Finally, from this latter reaction mixture, two additional products, neither of which are *C*-nucleosides, were isolated. One of these, 5-[1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-6-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (**14**) apparently arises by addition of the pyrimidinylpalladium species derived from **1** to 1,3-dimethyl-2,4-(1*H*,3*H*)-pyrimidinedione[29] present in the reaction mixture by reduction of **1**.[9] The second side product, formed in one reaction in trace amount, was identified as 3-[1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl]acrylonitrile (**15**) formed by palladium-catalyzed addition of **1** to acrylonitrile present as a trace contaminant in the acetonitrile solvent.[30]



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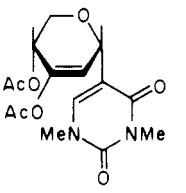

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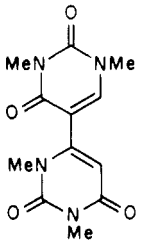

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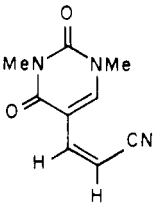


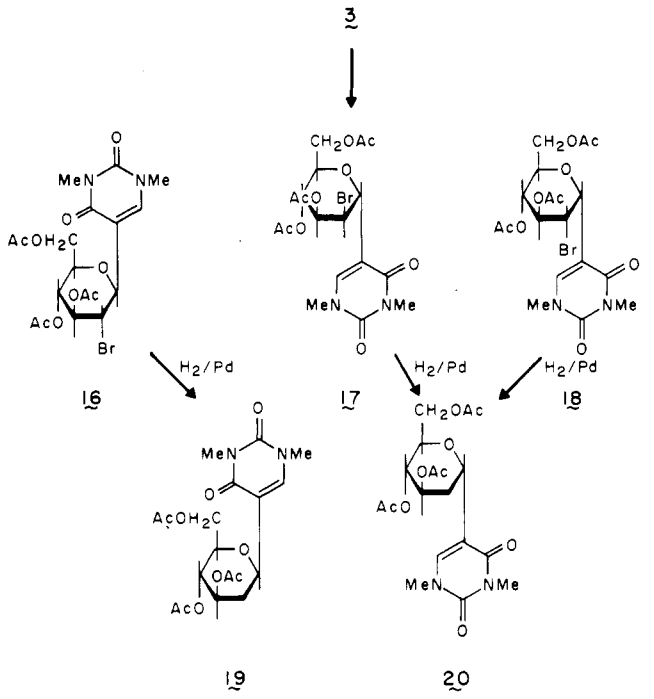
15

Cyclization of Acyclic *C*-Nucleoside 3. Treatment of (*Z*)-1,2-dideoxy-1-(1,2,3,4-tetrahydro-1,3-dimethyl-2,4-dioxo-5-pyrimidinyl)-D-*arabino*-hex-1-enitol 3,4,6-triacetate[2] (**3**), the acyclic *C*-nucleoside isolated in 72% yield from palladium-catalyzed reaction of **1** and **2** (Scheme I, Table I), with bromine in chloroform resulted in reformation of the glucopyranosyl ring affording three products (**16**–**18**) in 42, 20, and 6% yields, respectively (Scheme III). The major product, 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-bromo-2-deoxy-β-D-glucopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**16**), possesses the relative stereochemistry at carbohydrate ring carbons C-1 and C-5 (i.e., *cis*, β) characteristic of natural nucleosides including pseudouridine and many *C*-nucleoside antibiotics.[3] Catalytic hydrodebromination was facile affording the 2-deoxyglucopyrano *C*-nucleoside **19** which possesses interesting structural analogies with arabino nucleosides, many of which are bioactive.[31] Analogous hydrodebrominations of the minor, α-anomers **17** and **18** yielded a single *C*-nucleoside **20**; i.e., the α-anomer corresponding to **19**.

Spectrometric Properties of Products. Structural assignments are based on detailed analyses of spectrometric data and on chemical properties exhibited by the

(27) $J_{1,2e}$ is small.
(28) Hall, L. D. *Adv. Carbohydr. Chem.* **1964**, *19*, 51.
(29) Yamauchi, K.; Kinoshita, M. *J. Chem. Soc., Chem. Commun.* **1973**, 391.
(30) Kiesele, H. *Anal. Chem.* **1980**, *52*, 2230.
(31) Suhadolnik, R. J. "Nucleoside Antibiotics"; Wiley-Interscience: New York, 1970.

Scheme III. Cyclization of Acyclic C-Nucleoside 3



various compounds. A summary of these data is contained in Table II; in Figure 1 are ^{1}H NMR spectra showing the carbohydrate ring hydrogen resonances for bromo *C*-nucleosides **16–18** which illustrate the detailed analyses of coupling constants which permitted definitive assignments of structure to be made.

All but two of the compounds prepared exhibited molecular ions in electron ionization mass spectra. For compounds **4** and **8** no molecular ions were observed; loss of acetic acid gave rise to $[M - HOAc]^+$ ions at m/z 292 and 220, respectively. Mass spectra provided little structural information other than molecular composition since, in all instances, high mass ions arise by losses involving acetate groups of the carbohydrate moieties (i.e., AcOH, AcO; CH_2CO). It is noteworthy that ketene loss is prominent only in spectra of enol acetates **5** and **13** and aided in recognition of these products.

Ultraviolet spectrometry (Table II) provides a facile means for identifying the acyclic *C*-nucleoside products (**3** and **12**) which possess an altered chromophore owing to conjugation of a double bond within the carbohydrate moiety with the pyrimidine ring.[4,5]

^{1}H nuclear magnetic resonance spectra (Table II, Figure 1) contain data which, in most instances, permitted assignment of unique structures. For example, isomers **16–18** each possess conformations in which the pyrimidinyl moieties occupy equatorial positions as evidenced by (a) the chemical shifts of acetoxy methyl groups and (b) the coupling constants exhibited by carbohydrate ring hydrogens. All *C*-nucleosides derived from glucal exhibit a methyl hydrogen resonance at $\delta(CDCl_3)$ 2.06–2.09 assignable to the C-6 acetoxy function; resonances for methyl hydrogens of acetoxy groups at C-3 and C-4 appear at δ >2.09 when these groups are axial (e.g., in spectra of **17** and **18**) and at δ <2.06 when the acetoxy groups are equatorial (e.g., in the spectrum of **16**).[28] Examination of coupling constants for carbohydrate ring hydrogens[28,32] (Figure 1) confirms these conclusions and permits the relative configuration of the bromo substituents at C-2 to

(32) Hall, L. D. In "The Carbohydrates", 2nd ed.; Pigman, W., Horton, D., Eds; Academic Press: 1980; Vol. 1B, pp 1300–1326.

Table II. Chromatographic and Spectrometric Properties of 1,3-Dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl *C*-Nucleosides

compd	HPLC ret time, min	MS, m/z ($M^{+\cdot}$)	UV λ_{MeOH} (max), nm	^{1}H NMR ($CDCl_3$), δ									
				Py ring H	NMe	carbohydrate C-1H	C-2H	C-3H	C-4H	C-5H	C-6H	OAc
3	3.8,[a] 7.8[b]	412	282, 236	7.62	3.31, 3.40	6.34 (d)	5.55 (dd)	5.90 (dd)	5.10 (dd)	3.92 (m)	4.07 (d)	2.01, 2.04, 2.06
4	7.0[b]	292[e]	270	7.26	3.32, 3.39	5.33 (b)	6.14 (d)	5.91 (dd)	5.15 (b)	3.98 (m)	4.15–4.42	2.04
5	8.6[b]	410	270	7.36	3.32, 3.39	5.37 (b)	5.75 (d)		5.37 (b)	3.98 (m)	4.22 (m)	2.03, 2.06, 2.08
8		220[e]	270	7.25	3.37, 3.43	5.30 (b)	6.02 (m)		5.30 (b)	3.66 (dd), 4.17 (dd)		2.11
9	1.7[c]	280	270	7.21	3.34, 3.39	5.05 (b)	5.8–6.2 (m)		5.05 (b)	3.88 (dd), 4.10 (dd)		2.09
10		282	270	7.25	3.37, 3.43	4.35 (d)	1.3–2.4 (m)		4.83 (m)	4.11 (dd), 4.21 (dd)		2.09
11	1.9[c]	282	270	7.25	3.34, 3.41	4.39 (d)	1.4–2.1 (m)		4.83 (m)	3.72 (dd), 4.11 (dd)		2.12
12		340	282, 235	7.76	3.32, 3.42	6.42 (d)	5.53 (dd)	5.88 (dd)	4.93 (dt)	3.73 (d)		2.00, 2.03
13		338	270	7.34	3.36, 3.44	5.30 (m)	5.80 (dd)		5.30 (m)	3.98 (m)		2.07, 2.13
16	4.9[a]	490	270	7.25	3.36, 3.44	4.60 (d)	4.37 (t)	5.34 (t)	5.06 (t)	3.82 (m)	4.07 (dd), 4.24 (dd)	2.03, 2.05, 2.07
17	4.9[a]	490	270	7.35	3.35, 3.45	4.86 (d)	5.31 (dd)	5.39 (t)	4.88 (d)	4.23 (m)	4.01 (dd), 4.95 (dd)	2.06, 2.17, 2.21
18	5.8[a]	490	270	7.34	3.35, 3.46	5.05 (b)	4.57 (t)	5.49 (t)	4.88 (t)	4.34 (m)	4.26 (dd), 4.52 (dd)	2.09, 2.13, 2.18
19		412	270	7.25	3.32, 3.42	4.55 (d)	1.48 (dd), 2.59 (dd)	5.15 (m)	4.97 (t)	3.72 (m)	4.10 (dd), 4.29 (dd)	1.99, 2.04, 2.07
20	4.1[a]	412	270	7.33	3.33, 3.43	4.93 (dd)	~2.1 (m)	5.07 (dd)	4.81 (t)	4.15 (m)	4.23 (dd), 4.57 (dd)	2.07, 2.10, 2.13

[a] Methanol–water (1:1), Waters μ-Bondapak C_{18}, 7.8 × 300 mm, 5 mL/min. [b] Methanol–water (1:3), Waters μ-Bondapak C_{18}, 3.9 × 300 mm, 1 mL/min. [c] Methanol–water (1:2), Waters μ-Bondapak C_{18}, 3.9 × 300 mm. [d] Resonances for which no multiplicities are indicated are singlets; where multiplicities are noted the notation reflects the apparent multiplicities without consideration of spin–spin interactions. b, broad; d, doublet; t, triplet; m, multiplet; dd, doublet of doublets, dt, doublet of triplets. [e] $M^{+\cdot} - HOAc$.

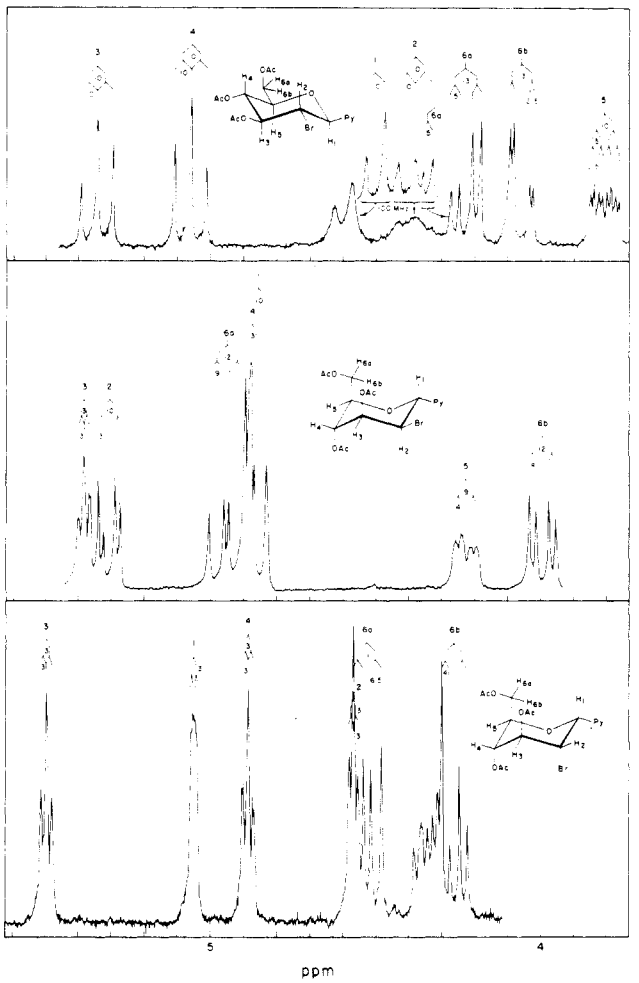


Figure 1. 200-MHz ^1H NMR spectra of the carbohydrate hydrogens of 2-bromoglucopyranosyl *C*-nucleosides **16–18** with analysis of spin–spin interactions which permit assignments of pyran conformations and substituent configurations: top, 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-bromo-2-deoxy-β-D-glucopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**16**); middle, 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-bromo-2-deoxy-α-D-mannopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**17**); bottom, 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-bromo-2-deoxy-α-D-glucopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**18**).

be established. Thus, in the spectra of **16** and **17**, $J_{1,2}$ = 10 Hz, showing that the bromo group is equatorial and trans to the pyrimidinyl moiety, whereas in the spectrum of **18** $J_{1,2}$ = 3 Hz indicative that the bromo substituent in axial and cis to the pyrimidinyl substituent at C-1.

Experimental Section

General Comments. Melting points were determined with a hot-stage microscope and are uncorrected. Ultraviolet spectra were recorded with a Cary-15 spectrophotometer, infrared spectra were recorded with a Perkin-Elmer 621 spectrometer, and NMR spectra were obtained by using Varian Associates HA-100 and JEOL FX90Q spectrometers. Mass spectra were obtained with a CEC (Du Pont) 21-110B mass spectrometer (direct insertion probe) or a Du Pont 21-491 gas chromatograph–mass spectrometer. High-resolution measurements were made by T. Wachs at Cornell University. High-pressure liquid chromatography (HPLC) was accomplished by using a Waters Associates instrument on octadecylsilane columns eluted with water–methanol mixtures. Column and thin-layer (TLC) chromatographies were carried out on silica gel. Elemental analyses were carried out by R. Wielesek, University of Oregon or Galbraith Laboratories, Knoxville, TN.

Reaction of (1,3-Dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl)mercuric Acetate[4] (1) with 3,4,6-Tri-*O*-acetyl-D-glucal[11] (2). A mixture of 2.2 g (10 mmol) of palladium acetate 0.8 g (20 mmol) of lithium chloride, 4 g (10 mmol) of **1**[4] and 4.1 g (15 mmol) of **2**[11] in 100 mL of acetonitrile was stirred at room temperature for 2 days. A stream of hydrogen sulfide was then passed through the reaction mixture for 15 min, and the insoluble material was removed by filtration. The solvent was evaporated, and the residue was chromatographed on silica gel using chloroform. Early fractions yielded 0.8 g of a mixture of 5-(4,6-di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranosyl)-1,3-dimethyl-2,4-(1*H*,3*H*)-pyrimidinedione (**4**) and 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-deoxy-α-D-*erythro*-hex-2-enopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**5**) in a ratio of approximately 1:1. Later fractions yielded 3 g (73%) of (*Z*)-1,2-dideoxy-1-(1,2,3,4-tetrahydro-1,3-dimethyl-2,4-dioxo-5-pyrimidinyl)-D-*arabino*-hex-1-enitol 3,4,6-triacetate (**3**).

Anal. Calcd for $C_{18}H_{24}N_2O_9$ (**3**): C, 52.4; H, 5.82; N, 6.80. Found: C, 52.2; H, 5.76; N, 6.95.

Separation of **4** and **5** was accomplished by HPLC using the conditions stated in Table II.

Anal. Calcd for $C_{16}H_{20}N_2O_7$ (**4**): C, 54.5; H, 5.68; N, 7.95. Found: C, 54.8; H, 5.91; N, 7.72.

Anal. Calcd for $C_{18}H_{22}N_2O_9$ (**5**): C, 52.7; H, 5.37; N, 6.82. Found: C, 52.6; H, 5.35; N, 7.09.

When the anion content of the reaction mixture was modified by varying the counterion (Cl^- or OAc^-) of the salts PyHgX, PdX_2, and LiX, and the yields of the respective products were altered as shown in Table I.

Reaction of (1,3-Dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl)mercuric Acetate[4] (1) with 3,4-Di-*O*-acetyl-D-arabinal[25] (6). A mixture of 1.1 g (5 mmol) of palladium acetate, 0.4 g (10 mmol) of lithium chloride, 2.0 g (5 mmol) of **1**[4] and 1.5 g (7.5 mmol) of **6**[25] in 100 mL of acetonitrile was stirred at room temperature for 1 day. Hydrogen sulfide was passed through the reaction mixture for 15 min, the precipitate was removed by filtration, the filtrate was evaporated, and the residue was chromatographed on silical gel using methylene chloride and then chloroform–ether (9:1) for elution to yield (2*R*-*trans*)-5-[5-(acetyloxy)-5,6-dihydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione[2] (**8**), 290 mg (20%), and (*Z*)-1,2-dideoxy-1-(1,2,3,4-tetrahydro-1,3-dimethyl-2,4-dioxo-5-pyrimidinyl)-D-*erythro*-pent-1-enitol 3,4-diacetate[2] (**12**), 550 mg (32%).

Anal. Calcd for $C_{13}H_{16}N_2O_5$ (**8**): C, 55.7; H, 5.71; N, 10.0. Found: C, 55.9; H, 5.89; N, 9.82.

Anal. Calcd for $C_{15}H_{20}N_2O_7$ (**12**): C, 52.9; H, 5.88; N, 8.24. Found: C, 53.0; H, 5.97; N, 8.02.

Hydrogenation of (2*R*-*trans*)-5-[5-(Acetyloxy)-5,6-dihydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione[2] (8). To a solution of 200 mg of **8** in 50 mL of methanol was added 20 mg of 10% palladium on charcoal. The resulting mixture was shaken under 2 atm of hydrogen for 2 h. The catalyst was removed, the solvent was evaporated, and the residual crude product was purified by HPLC (H_2O–MeOH, 2:1) to yield 160 mg of (2*R*-*trans*)-5-[5-(acetyloxy)-3,4,5,6-tetrahydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (**10**).

Reaction of (1,3-Dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-5-yl)mercuric Acetate[4] (1) with 3,4-Di-*O*-acetyl-D-xylal[26] (7). A mixture of 1.65 g (7.5 mmol) of palladium acetate; 0.6 g (15 mmol) of lithium chloride in 75 mL of acetonitrile was stirred at room temperature for 24 h. Then 3 g (7.5 mmol) of **1** and a solution of 2.25 g (11.25 mmol) of **7** in 50 mL of acetonitrile were added, and the mixture was stirred at room temperature for 48 h. A stream of hydrogen sulfide was passed through the reaction mixture for 15 min, and the precipitated metal salts were removed by filtration. The solvent was removed from the filtrate under reduced pressure, and the residue was chromatographed over silica gel using ethyl acetate–petroleum ether (3:1), ethyl acetate, and ethyl acetate–methanol (4:1) for elution. Early fractions yielded a residue (690 mg) which was dissolved in a small volume of ether and refrigerated overnight. The solid which formed (102 mg) was separated, shown to be homogeneous by HPLC and identified by its spectrometric properties (Table II) as (2*S*-*cis*)-5-[5-(acetyloxy)-5,6-dihydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (**9**). Mass spectrum: calculated for M^+ – HOAc, $C_{11}H_{12}N_2O_3$, 220.0848: Found, 220.0848. The remaining material, recovered by evaporation of the filtrate, was separated by HPLC (Table II) to yield an additional 104 mg of **9** and (2*S*-*cis*)-5-[4,5-bis(acetyloxy)-5,6-dihydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4-

(1*H*,3*H*)-pyrimidinedione (**13**), 200 mg (eluted last).

Anal. Calcd for $C_{15}H_{18}N_2O_7$: C, 53.3; H, 5.33; N, 8.28. Found: C, 53.1; H, 5.17; N, 8.12.

The final column eluate (ethyl acetate–methanol, 4:1) yielded 5-[1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedion-6-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione[10] (**14**): 365 mg; mass spectrum, *m/z* 278 ($M^{+\cdot}$, 100%); UV λ_{max} (EtOH) 269, 280 (sh) nm; ^1H NMR ($CDCl_3$) 3.32, 3.40, 3.44, 3.53 (N-Me), 5.66 (C-5H), 7.39 (C-6H).

In one experiment, a small amount of 3-[1,3-dimethyl-2,4-(1*H*,3*H*)-pyrimidinedion-5-yl]-acrylonitrile (**15**): mass spectrum, *m/z* 191 ($M^{+\cdot}$, 100%), 164, 134, 106; UV λ_{max} (EtOH), 313, 255, 221 nm; ^1H NMR ($CDCl_3$) 3.38, 3.51 (NMe), 5.33 (C-2H, d, J = 12 Hz), 7.29 (C-3H, d, J = 12 Hz), 8.35 (C-6H, s).

Hydrogenation of (2*S*)-*cis*)-5-[5-(Acetyloxy)-5,6-dihydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4(1*H*,3*H*)pyrimidinedione (9). To a solution of 180 mg of **9** in 50 mL of tetrahydrofuran was added 20 mg of 10% palladium on charcoal. The resulting mixture was shaken under 2 atm of hydrogen for 2 h. The catalyst was removed, the solvent was evaporated, and the residue was fractionated by HPLC (H_2O–MeOH, 2:1) to yield 125 mg of (2*S*-*cis*)-5-[5-(acetyloxy)-3,4,5,6-tetrahydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4-(1*H*,3*H*)-pyrimidinedione (**11**) and 19 mg of 5-[3,4,5,6-tetrahydro-2*H*-pyran-2-yl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimdinedione.[4]

Treatment of (*Z*)-1,2-Dideoxy-1-(1,2,3,4-tetrahydro-1,3-dimethyl-2,4-dioxo-5-pyrimidinyl)-D-*arabino*-hex-1-enitol 3,4,6-triacetate[2] (3) with Bromine. To 1.5 g of **3** in 150 mL of chloroform cooled to 0 °C was added dropwise a solution of bromine in chloroform until color persisted. The solvent was then evaporated, and the residue was chromatographed on silica gel using hexane–ethyl acetate (1:2) for elution. Two major elution bands were observed. The first, 0.84 g, was further separated by preparative liquid chromatography (see Table II) to yield 0.74 g (42%) of 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-bromo-2-deoxy-β-D-glucopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**16**) and 0.1 g (6%) of 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-bromo-2-deoxy-α-D-glucopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**18**). The second band eluted from the silica gel column consisted of 0.36 g (20%) of 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-bromo-2-deoxy-α-D-mannopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**17**). Characterizing data which permit assignment of these structures are contained in Table II and Figure 1.

Hydrodebromination of Bromonucleosides 16, 17, and 18. A mixture of 0.1 g of **16**, **17**, or **18**, 1 mL of triethylamine, and 50 mg of 5% palladium on carbon in 50 mL of methanol was shaken under 2 atm of hydrogen for 1 h. The catalyst was removed by filtration, the solvent was evaporated, and the residue was chromatographed on silica gel using ether for elution to yield (from **16**) 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-deoxy-β-D-*arabino*-hexopyranosyl)-2,4(1*H*,3*H*)-pyrimidinidione (**19**) or (from **17** or **18**) 1,3-dimethyl-5-(3,4,6-tri-*O*-acetyl-2-deoxy-α-D-*arabino*-hexopyranosyl)-2,4(1*H*,3*H*)-pyrimidinedione (**20**) in essentially quantitative yields. Characterizing data for **19** and **20** are contained in Table II.

Anal. Calcd for $C_{18}H_{24}N_2O_9$: C, 52.4; H, 5.82; N, 6.80. Found for **19**: C, 52.6; H, 5.98; N, 6.72. Found for **20**: C, 52.3; H, 5.89; N, 6.83.

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