# Synthesis of 3′,7′-anhydrooctose nucleosides related to the ezomycins and the octosyl acids

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*This paper is dedicated to Prof. Raymond U. Lemieux on the occasion of his 60th birthday*

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Several novel 3′,7′-anhydrooctose nucleosides, including a 3′,7′-anhydroocturonic acid nucleoside, namely 1-(3,7-anhydro-5,6-dideoxy-β-D-*allo*-octofuranosyluronic acid)-3-methyluracil (**40**), have been synthesized. The synthetic sequence leading to **40** consists of three key steps: preparation of an octose nucleoside by a chain extension of an uridine derivative using a Wittig reaction, conversion of the octose nucleoside into a bicyclic-octose nucleoside by an intramolecular cyclization, and elaboration of a carboxylic acid function at the C-8′ position of the bicyclic-octose nucleoside. The structures of the 3′,7′-anhydrooctose nucleosides have been established by their uv, $^1$Hmr, $^{13}$Cmr, and mass spectral data.

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On a synthétisé plusieurs nucléosides du type anhydro-3′,7′ octose dont le nucléoside de l'acide anhydro-3′,7′ octuronique, soit (l'acide anhydro-3,7 didéoxy-5,6 β-D-*allo*-octofurannosyluronique)-1 méthyl-3 uracil (**40**). La synthèse comprend 3 étapes principales; la première étape consiste à préparer un nucléoside de type octose par élongation de la chaîne d'un dérivé de l'uridine en utilisant une réaction de Wittig. Dans la deuxième étape, on transforme l'octose en un nucléoside bicyclique en faisant appel à une cyclisation intramoléculaire. La troisième étape permet de fixer une fonction acide carboxylique en position C′-8 du nucléoside octose bicyclique. On a établi les structures des nucléosides anhydro-3′,7′ octose en se basant sur les données des spectres uv, rmn du $^1$H et du $^{13}$C et de la spectrométrie de masse.

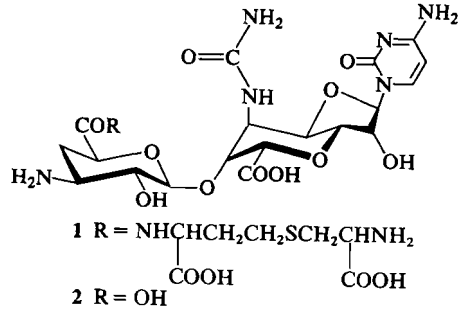
[Traduit par le journal]

## Introduction

The synthesis of carbohydrates containing carbon chains composed of more than six carbon atoms, carbohydrates which have been called higher-carbon sugars (1), has posed a considerable challenge. Such syntheses require the creation of C—C bonds together with control of the absolute stereochemistry at every carbon center. It is noteworthy that the concept of asymmetric synthesis was first realized by Emil Fischer's cyanohydrin reaction with carbohydrates (2). Added impetus has, in recent years, been given to this area of carbohydrate chemistry, by the development of new methods of chain extension (3) and by the discovery of various important antibiotics containing highly complex, higher-carbon sugars, such as lincomycin (4), celesticetin (5), apramycin (6), oxyapramycin (7), the ezomycins (8), mildiomycin (9), tunicamycin (10), and hikizimycin (11).

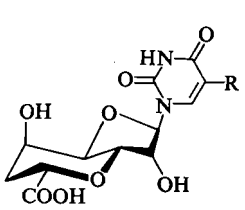
A major program in this laboratory has been concerned with the development of new methods of chain extension and with the synthesis of antibiotics containing higher-carbon sugars and of related systems; some methods (12) and the synthesis of lincomycin (13) were reported several years ago, and, recently, the synthesis of the octodiose related to apramycin has been also accomplished in this laboratory (14).

The present study is concerned with the ezomycins (15, 16) and the octosyl acids (17) which were obtained from two different strains of *Streptomyces* and which contain a unique type of higher-carbon sugar.



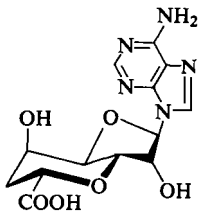
**1** R = NHCHCH$_2$CH$_2$SCH$_2$CHNH$_2$ (COOH, COOH)

**2** R = OH



**3** R = COOH

**4** R = CH$_2$OH



**5**

The sugar, a 3,7-anhydrooctonic acid in ezomycins $A_1$ (**1**), $A_2$ (**2**), $B_1$, $B_2$, $C_1$, and $C_2$ (**8**) and in octosyl acids A (**3**) and B (**4**) (17), is the first octose derivative containing a rigid bicyclic system in which a furanoid ring is *trans*-fused to a pyranoid ring. In spite of their structural similarities, the ezomycins and octosyl acids show marked differences in biological activities. Thus, whereas the

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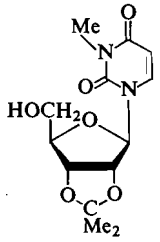
ezomycins are antifungal antibiotics (16), the octosyl acids are devoid of any such activity.

However, the adenine analog (**5**) of the octosyl acids, readily obtained from **3** by transglycosylation (18, 19), was found to be an inhibitor of cyclic-AMP phosphodiesterases from various animal tissues (19). In fact, octosyl acids **3** and **4** may be regarded as carboanalogs of 3′,5′-cyclic nucleotides. The unique structures and the biological activities of the ezomycins and the octosyl acids have inspired various studies related to these compounds during the last few years. For example, a biosynthesis of octosyl acid A has been accomplished by Sato *et al.* (20), and a synthesis of an octose derivative related to the octosyl acids has been attempted (21). A $^{13}$Cmr spectroscopic study of the ezomycins has been also reported (22).

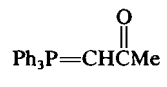
The present article describes the first synthesis of 3′,7′-anhydrooctose nucleosides and of a 3′,7′-anhydrooctcuronic acid nucleoside.

## Results and Discussion

On the basis of a retrosynthetic analysis, it seemed most appropriate to prepare an octose nucleoside from a ribonucleoside by a three-carbon chain extension followed by cyclization of the octose nucleoside to afford a 3′,7′-anhydrooctose nucleoside. As the starting material, the readily available 2′,3′-isopropylidene-3-methyluridine (**6**) (23) was chosen. This compound could be prepared from 2′,3′-*O*-isopropylideneuridine in large quantities more easily by methylation with *N*,*N*-dimethylformamide dimethyl acetal. For the chain extension of **6**, the three Wittig reagents **7**, **8**, and **9** were chosen. Although the Wittig reagent **7** would not provide functionality at C-8′ of the 3′,7′-anhydrooctose nucleoside, nevertheless, because of its ready availability (24) and simple structure, **7** was employed, prior to the use of Wittig reagents **8** and **9**, for the synthesis of prototype compounds, especially in order to examine the formation of the *trans*-fused, bicyclic ring system.



**6**



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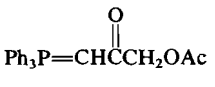

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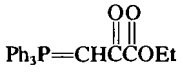

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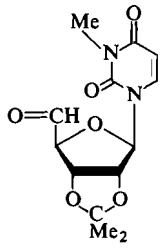
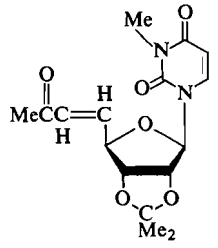
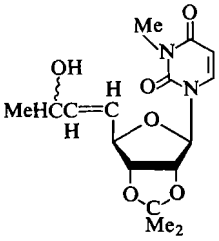


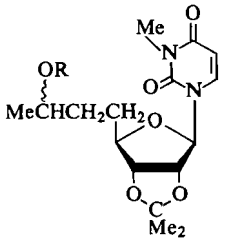
**10**



**11**

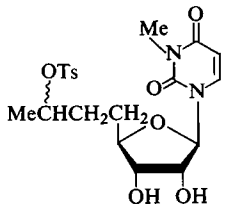


**12**

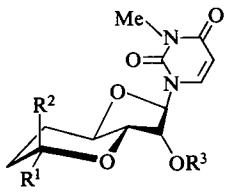


**13** R = H
**14** R = Ts

The aldehyde **10**, obtained by oxidation of **6** and employed without isolation from the reaction mixture, was allowed to react with the Wittig reagent **7**. Chromatographic purification afforded the α,β-(*E*)-unsaturated ketone **11** in 77% yield from **6**. The $^1$Hmr spectrum of **11** showed a doublet of doublets ($J_{5',6'}$ = 16 Hz, $J_{4',5'}$ = 6 Hz) at δ 6.89 for H-5′ and a singlet at δ 2.29 for H-8′. Compound **11** was reduced with sodium borohydride to give a chromatographically homogeneous, epimeric mixture, namely 1-[(*E*)-5,6,8-trideoxy-2,3-*O*-isopropylidene-β-D-*allo* (and α-L-*talo*)-oct-5-enofuranosyl]-3-methyluracil (**12**). The $^1$Hmr spectrum of **12**, however, indicated that small amounts of the saturated alcohols **13**, which are the desired products of the next step, were also generated during the borohydride reduction of **11**. Catalytic hydrogenation of the allylic alcohols **12** in the presence of 10% palladium-on-charcoal afforded the saturated alcohols **13**. Treatment of **13** with *p*-toluenesulfonyl chloride gave **14**. The isopropylidene groups in **14** were cleaved using 90% formic acid at 0°C to afford the diols **15** in 78% yield. Cyclization was accomplished by treatment of the *p*-tolylsulfonates **15** with sodium hydride in *N*,*N*-dimethylformamide at room temperature. Two epimeric 3′,7′-anhydrooctose nucleosides were separated by column chromatography. The crystalline, faster-moving



15



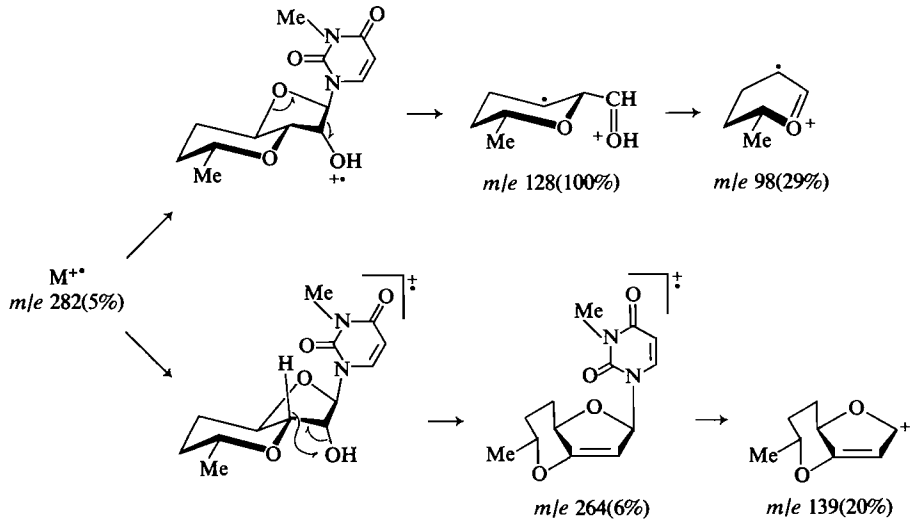
16 $R^1$ = Me, $R^2$ = $R^3$ = H
17 $R^1$ = $R^3$ = H, $R^2$ = Me
18 $R^1$ = Me, $R^2$ = H, $R^3$ = Ac
19 $R^1$ = H, $R^2$ = Me, $R^3$ = Ac

isomer was identified as being 1-(3,7-anhydro-5,6,8-trideoxy-β-D-*allo*-octofuranosyl)-3-methyluracil (**16**) (25%). The slower-moving isomer, namely 1-(3,7-anhydro-5,6,8-trideoxy-α-L-*talo*-octofuranosyl)-3-methyluracil (**17**), was obtained as a syrup in 21% yield. Acetylation of **16** and **17** afforded monoacetates **18** and **19**, respectively.

The *trans*-fused bicyclic system of compounds **16** and **17** is supported by a sharp singlet ($J_{1',2'}$ = 0 Hz) owing to H-1′ protons in their $^1$Hmr spectra. Usually the $^1$Hmr spectra of uridine derivatives show a doublet for the anomeric proton. The $J_{1',2'}$ value of **15**, which is the immediate precursor of **16** and **17**, is 3.5 Hz. The zero value of $J_{1',2'}$ of **16** and **17** corresponds to a C-3′ *endo* conformation of the furanose ring and a *trans* relationship between H-1′ and H-2′. Small or zero values of $J_{1',2'}$ have been observed in the cases of 3′,5′-cyclic nucleotides (25), the ezomycins (8), and the octosyl acids (17). The mass spectra of **16** and **17** reflect very clearly the bicyclic nature of the molecules. The mass spectrum of **16** shows characteristic nucleoside-base peaks at *m/e* 155 (b + 30), *m/e* 127 (b + 2H), and *m/e* 126 (b + H) (26). In addition to these prominent ions, a major mode of fragmentation, not observed in other nucleoside spectra, is represented by the most intense peak at *m/e* 128, owing to the species formed from the molecular ion by the opening of the ribose ring, and a peak at *m/e* 98 owing to further decomposition of this species (see Scheme 1). Comparable fragmentation patterns have been observed in the spectra of 3′,5′-cyclic nucleotides (27). The intact sugar fragment is absent in this mass spectrum; however, the ion (*m/e* 139), formed from the molecular ion by the elimination of $H_2O$ and subsequent cleavage of the glycosidic bond, is comprised of the entire bicyclic-sugar carbon skeleton.

The stereochemistry at C-7′ of **16** and **17** was assigned on the basis of their $^{13}$Cmr and $^1$Hmr chemical-shift data. The epimer, whose C-8′ signal resonated at δ 21.0 in its $^{13}$Cmr spectrum, was assigned as being compound **16** bearing an equatorial methyl group, whereas the compound whose C-8′ signal was at δ 17.5 in its $^{13}$Cmr spectrum was assigned as being compound **17** bearing an axial methyl group. In their $^1$Hmr spectra, the resonance for the H-8′ protons of **16** (δ 1.32) appears at slightly higher field than that of **17** (δ 1.36). It has been well established that, whereas the carbon resonance of an equatorial methyl group in cyclohexane and 1,3-dioxane systems (28) shifts downfield relative to that of the corresponding axial one, the protons of an equatorial methyl group in cyclohexane, 1,3-dioxane, and 1,3,5-trioxane systems (29) resonate at higher field than do those of the corresponding axial one.

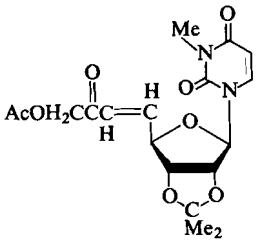
The initial studies established the feasibility of the synthesis of a 3′,7′-anhydrooctose nucleoside



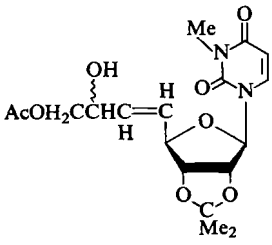

SCHEME 1

by the approach described above. Attention was then directed to the functionalization of the C-5′, C-6′, and C-8′ positions, a process which is required for the eventual total synthesis of the ezomycins and the octosyl acids. Although the C-5′—C-6′ double bond in compounds **11** and **12** can be easily functionalized, the introduction of functionality at C-8′ is not feasible at any stage of the above synthetic sequence. This problem was solved by employing another Wittig reagent, namely **8** (30), which could be prepared in a reasonable quantity relatively easily using a modified procedure. Wittig reagent **9** (31) would be more suitable than **8** for the introduction of the carboxylic acid function at C-8′, however, the product of a Wittig reaction of **9** and **10** decomposed during the course of the reaction and subsequent processing.

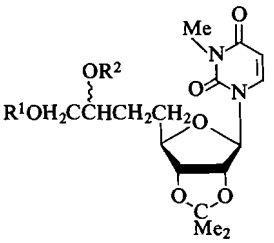
A Wittig reaction of **8** and **10** afforded after chromatography the syrupy α,β-(*E*)-unsaturated ketone **20** in 72% yield from **6**. The $^1$Hmr spectrum of **20** showed a large *trans*-ethylenic coupling constant ($J_{5',6'}$ = 16 Hz). Compound **20** was reduced with sodium borohydride in absolute ethanol at −20°C to afford a chromatographically homogeneous, epimeric mixture, namely 1-[(*E*)-8-*O*-acetyl-5,6-dideoxy-2,3-*O*-isopropylidene-β-D-*allo* (and α-L-*talo*)-oct-5-enofuranosyl]-3-methyluracil (**21**). The allylic alcohols **21** were converted by catalytic hydrogenation into the saturated alcohols **22**. The reaction of **22** with *p*-toluenesulfonyl chloride afforded **23**. Cleavage of the isopropylidene groups of **23** was accomplished with 90% formic acid at 0°C to give **24** in 75% yield.



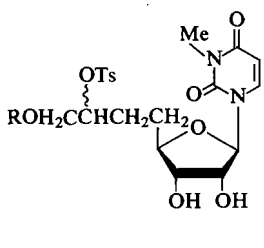

**20**




**21**



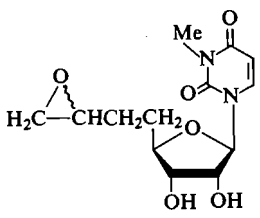

**22** $R^1$ = Ac, $R^2$ = H
**23** $R^1$ = Ac, $R^2$ = Ts
**27** $R^1$ = $CH_2CH{=}CH_2$, $R^2$ = H
**28** $R^1$ = $CH_2CH{=}CH_2$, $R^2$ = Ts




**24** R = Ac
**29** R = $CH_2CH{=}CH_2$

Treatment of **24** with sodium hydride in dry 1,2-dimethoxyethane or *N*,*N*-dimethylformamide unexpectedly gave a complex multiplicity of products. One of the major products was identified as being an oxirane derivative (**25**). However, the desired 3′,7′-anhydrooctose nucleoside was not detected. Although this attempted cyclization reaction was not fully investigated, the complication of the reaction might be attributable to the lability of the acetyl group under the reaction conditions. The acetyl groups in **23** were replaced by allyl groups (32) by a sequence of three steps: (*i*) conversion of **23** into a mixture of oxiranes using sodium methoxide in chloroform; (*ii*) ring opening of the oxiranes **26** with sodium alloxide in allyl alcohol at room temperature; (*iii*) treatment of the resulting secondary alcohols **27** with *p*-toluenesulfonyl chloride. The oxirane ring opening of **26** with alloxide was regioselective and provided the expected secondary alcohol **27** exclusively in 88% yield. The $^1$Hmr spectrum of **27** showed a two-proton multiplet at δ 5.03–5.34 owing to two terminal vinylic protons and an one-proton multiplet at δ 5.58–6.39 attributable to another vinylic proton of the allyl group. The *p*-tolylsulfonates **28** obtained in this way were converted into **29** in 89% yield by treatment with 90% formic acid at 0°C.

The stage was again set for the elaboration of the bicyclic ring system. Cyclization was accomplished by treatment of **29** with sodium hydride in 1,2-dimethoxyethane at room temperature to afford a chromatographically homogeneous, epimeric mixture (**30**) in 50% yield. A sharp singlet at δ 5.65 owing to anomeric protons in the $^1$Hmr spectrum of **30** indicated the *trans*-fused bicyclic structure. The allyl groups in **30** were isomerized to prop-1-enyl groups by treatment with $RhCl(PPh_3)_3$ in refluxing aqueous ethanol (33). At this stage the two epimers could be separated by careful column chromatography to afford pure **31** in 45% and **32** in 42% yield. The $^1$Hmr spectrum of **31** showed a three-proton doublet of doublets at δ 1.56 attributable to the allylic-methyl protons of the prop-1-enyl group and a one-proton multiplet at δ 5.86–6.30 attributable to a vinylic proton on the carbon next to the oxygen atom of the prop-1-enyl group. The $^1$Hmr spectrum of **32** also showed similar patterns of signals at δ 1.58 and at δ 5.91–6.32. The stereochemistry at C-7′ of the two epimers **31** and **32** was not assigned at this stage; however, it could be established later by the structural assignment of the two epimers **35** and **36** which were derived from **31** and **32**, respectively. Benzoylation of **31** and **32** gave monobenzoates **33** and **34**, respectively. Removal of the prop-1-enyl groups in **33** and **34** was



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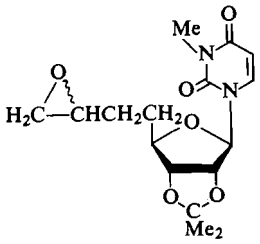

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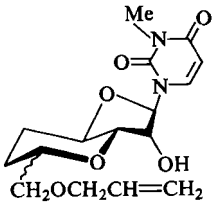

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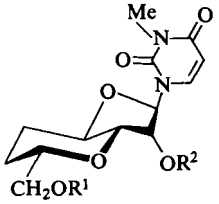
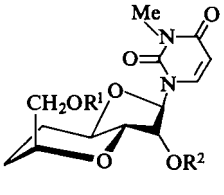


31 $R^1$ = CH=CHCH$_3$, $R^2$ = H
33 $R^1$ = CH=CHCH$_3$, $R^2$ = Bz
35 $R^1$ = H, $R^2$ = Bz
37 $R^1$ = $R^2$ = H

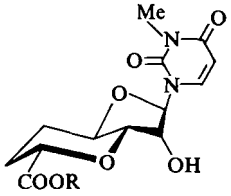
accomplished with 0.1 *N* hydrochloric acid in aqueous methanol at room temperature (32) to afford 1-(3,7-anhydro-2-*O*-benzoyl-5,6-dideoxy-β-D-*allo*-octofuranosyl)-3-methyluracil (**35**) and 1-(3,7-anhydro-2-*O*-benzoyl-5,6-dideoxy-α-L-*talo*-octofuranosyl)-3-methyluracil (**36**), respectively. Hydrolysis of the prop-1-enyl groups in **33** and **34** with mercuric chloride in the presence of mercuric oxide (34) resulted in the partial decomposition of products **35** and **36**. The stereochemistry at C-7′ of compounds **35** and **36** was readily assigned in a manner similar to that used for the assignments in the cases of the bicyclic octose nucleosides **16** and **17**. Thus, the C-8′ signal in the $^{13}$Cmr spectrum of one epimer appeared at δ 65.0 and that of another epimer appeared at δ 60.9. The former was assigned as being compound **35** bearing an equatorial hydroxymethyl group and the latter as being compound **36**. The stereochemistry at C-7′ of compounds **31–34**, thereby, could be correctly assigned.

Thus, the synthesis of a 3′,7′-anhydrooctose nucleoside with a functional group at C-8′ has been accomplished. Finally, the hydroxymethyl group of compound **35** was further transformed into a carboxylic acid function. Oxidation of **35** with chromium(VI) reagents was not very satisfactory, mainly because the isolation of the product from the reaction mixture was difficult or very tedious owing to the solubility of the product. Better results could be obtained by employing catalytic oxidation. Thus, compound **37**, obtained from **35** by debenzoylation, was oxidized in the presence of 10% platinum-on-charcoal at pH 8–9 at 70°C to give 1-(3,7-anhydro-5,6-dideoxy-β-D-*allo*-octofuranosyluronic acid)-3-methyluracil (**39**) in 74% yield. Treatment of **39** with 3% hydrogen chloride in methanol afforded the methyl ester **40**. The $^1$Hmr spectrum of **40** showed a three-proton singlet at δ 3.75 attributable to the methyl ester at C-8′. The ir spectrum of **40** showed a broad band at 3430 cm$^{-1}$.

The sequence leading to the 3′,7′-anhydroocturonic acid nucleoside as described in this paper can be adapted to the synthesis of the ezomycins, the octosyl acids, and their analogs. Further investigations into the functionalization at C-5′ and C-6′ of the 3′,7′-anhydrooctose nucleoside are currently underway, and a different approach to the synthesis of 3′,7′-anhydrooctose nucleosides will be reported separately.



32 $R^1$ = CH=CHCH$_3$, $R^2$ = H
34 $R^1$ = CH=CHCH$_3$, $R^2$ = Bz
36 $R^1$ = H, $R^2$ = Bz
38 $R^1$ = $R^2$ = H



39 R = H
40 R = Me

## Experimental

Evaporations were performed under reduced pressure at or below 40°C (bath temperature). Melting points were determined on a Fisher–Johns apparatus and are uncorrected. Optical rotations were measured with a Perkin–Elmer model 141 automatic polarimeter at 23 ± 3°C. Infrared spectra were recorded with a Perkin–Elmer 180 or a Perkin–Elmer 598 infrared spectrophotometer. Ultraviolet spectra were measured with a Unicam SP 800B or a Perkin–Elmer 552 spectrophotometer. The $^1$Hmr spectra were determined with a Varian EM-360 or Bruker HX-60 spectrometer in chloroform-*d* with tetramethylsilane (TMS) as the internal standard, unless otherwise stated. The $^{13}$Cmr were recorded in chloroform-*d* solution on a Bruker HX-60 spectrometer equipped with an FT60M Fourier transform accessory at 15.09 MHz; chemical shifts are given in parts per million downfield from TMS. Mass spectra were taken on a Jeolco model JMS-015C spectrometer using the direct-sample inlet system with a 70 eV ionization energy. Microanalyses were performed by Guelph Chemical Laboratories Ltd., Guelph, Ont. Thin-layer chromatography (tlc) was performed on precoated glass plates (silica gel 60 F-254, 0.25 mm thickness) from EM Laboratories Inc., using the following solvent systems (v/v): (*A*) toluene–acetone, 1:1; (*B*) toluene – ethyl acetate, 1:1; (*C*) toluene–acetone, 2:1; (*D*) toluene – ethyl acetate, 2:1; (*E*) ethyl acetate; (*F*) ethyl acetate – methanol, 2:1; (*G*) *n*-butanol – methanol–water, 8:1:1. The developed plates were air dried and compounds located by irradiation of the plates with uv light and by heating the plates at 150°C after they had been sprayed with 10% aqueous sulfuric acid containing 1% cerium sulfate and 1.5% molybdic acid. Column chromatography was performed on Brinkmann silica gel 60 (70–230 mesh, E. Merck). E. Merck precoated glass plates (silica gel F-254, 20 × 20 cm, 2 mm thickness) were used for preparative tlc chromatography.

*2',3'-O-Isopropylidene-3-methyluridine (6)*

A suspension of 2',3'-*O*-isopropylideneuridine (35) (7.1 g, 20 mmol) and *N,N*-dimethylformamide dimethyl acetal (9.5 g, 80 mmol) in chloroform (80 mL) was heated at reflux temperature with vigorous stirring. The mixture became homogeneous within 30 min. After 8 h the solvent was evaporated to give a reddish syrup which slowly crystallized on standing. Recrystallization from ethanol–ether gave compound **6** (6.5 g, 87%) having $R_f$ 0.57 (solvent *A*), mp 133–134°C (lit. (10) mp 133.5–134°C); $^1$Hmr δ: 1.38 (3H, s, Me), 1.60 (3H, s, Me), 3.33 (3H, s, NMe), 3.55–3.92 (3H, m, H-4', 2(H-5')'s), 4.29 (1H, bs, OH, exchanged in $D_2O$), 4.74–5.02 (2H, m, H-2', H-3'), 5.73 (1H, d, $J_{1',2'}$ = 1.2 Hz, H-1'), 5.74 (1H, d, $J_{5,6}$ = 8 Hz, H-5), 7.60 (1H, d, H-6).

*1-[(E)-5,6,8-Trideoxy-2,3-O-isopropylidene-β-D-ribo-oct-5-eno-1,4-furanosid-7-ulosyl]-3-methyluracil (11)*

To a solution of **6** (2.39 g, 8 mmol) in dimethylsulfoxide (40 mL), stirred at room temperature under nitrogen, pyridine (0.64 mL), trifluoroacetic acid (0.30 mL), and *N,N'*-dicyclohexylcarbodiimide (4.96 g, 24 mmol) were added. After 12 h, the Wittig reagent **7** (3.31 g, 10.4 mmol) was added and stirring was continued for a further 24 h at room temperature. Oxalic acid dihydrate (2.9 g) and ethyl acetate (200 mL) were then added and the mixture was stirred for 10 min. This mixture was poured into saturated sodium chloride solution (100 mL), stirred for a few min, and filtered. The separated aqueous layer was extracted once more with ethyl acetate (80 mL). The combined ethyl acetate solutions were washed with dilute aqueous sodium hydrogen carbonate, saturated aqueous sodium chloride, and cold water, dried ($MgSO_4$), and evaporated to give a dark red syrup. The thick syrup was dissolved again in ethyl acetate and insoluble *N,N'*-dicyclohexylurea was removed by filtration. This procedure was repeated a few more times to remove *N,N'*-dicyclohexylurea. The resulting red syrup (5.5 g) was chromatographed on a column of silica gel by elution with toluene – ethyl acetate, 7:5 (v/v), to afford **11** as a colorless syrup (2.07 g, 77%) having $R_f$ 0.23 (solvent *B*); $[\alpha]_D$ +54.8° (*c* 0.062, $CHCl_3$); ir (film) $\nu_{max}$: 1710, 1680, 1665, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 217 (ε 13 000), 259 (6800) nm; $^1$Hmr δ: 1.38 (3H, s, isopropylidene-Me), 1.59 (3H, s, isopropylidene-Me), 2.29 (3H, s, H-8''s), 3.32 (3H, s, NMe), 4.51–5.17 (3H, m, H-2'–H-4'), 5.61 (1H, d, $J_{1',2'}$ = 1.2 Hz, H-1'), 5.78 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 6.22 (1H, d, $J_{5',6'}$ = 16.0 Hz, H-6'), 6.89 (1H, dd, $J_{4',5'}$ = 6.0 Hz, H-5'), 7.27 (1H, d, H-6). *Anal.* calcd. for $C_{16}H_{20}N_2O_6$: C 57.14, H 5.99, N 8.33; found: C 57.33, H 6.24, N 7.73.

*1-[(E)-5,6,8-Trideoxy-2,3-O-isopropylidene-β-D-allo (and α-L-talo)-oct-5-enofuranosyl ]-3-methyluracil (12)*

To a stirred solution of **11** (1.62 g, 4.8 mmol) in ethanol (30 mL) was added sodium borohydride (0.19 g, 5.0 mmol) at 0°C in the dark. Thin-layer chromatography (solvent *C*) showed that after 5 min the reaction mixture contained only one component ($R_f$ 0.33) but no starting material. The reaction mixture was carefully neutralized with 1 *N* hydrochloric acid and the neutral mixture was evaporated to a residue which was concentrated several times with methanol. The residue was extracted with hot ethyl acetate (4 × 30 mL) and the extract was filtered through a small amount of silica gel. Evaporation of the solvent gave **12** as a chromatographically homogeneous white foam (1.60 g, 98%). An analytical sample was obtained by preparative tlc using toluene–acetone, 1:1 (v/v), as eluent; ir (film) $\nu_{max}$: 3430, 1710, 1670, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 212 (ε 6800), 258 (9800) nm; $^1$Hmr δ: 1.26 (3H, d, $J_{7',8'}$ = 6.0 Hz), 1.34 (3H, s, isopropylidene-Me), 1.58 (3H, s, isopropylidene-Me), 2.67 (1H, bs, OH, exchanged in $D_2O$), 3.30 (3H, s, NMe), 3.67–5.02 (4H, H-2'–H-4', H-7'), 5.49–5.90 (2H, m, H-5', H-6'), 5.64 (1H, d, $J_{1',2'}$ = 1.2 Hz, H-1'), 5.73 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.26 (1H, d, H-6).

*1-[5,6,8-Trideoxy-2,3-O-isopropylidene-β-D-allo (and α-L-talo)-octofuranosyl]-3-methyluracil (13)*

A solution of **12** (2.15 g, 6.3 mmol) in ethanol (150 mL) was shaken in a standard Paar bottle together with 10% palladium-on-charcoal catalyst (0.35 g) under a 1-atm hydrogen pressure at room temperature. As soon as the shaking was started, hydrogen was consumed very rapidly. After 10 min the hydrogen uptake had almost ceased. Thin-layer chromatography (solvent *C*) showed that the $R_f$ value of the product was the same as that of the starting material. The reaction mixture was filtered through Celite twice and the filtrate was concentrated to a white foam which was chromatographed on a column of silica gel by elution with toluene – ethyl acetate, 5:6 (v/v), to give **13** as a white foam (1.81 g, 84%); ir (film) $\nu_{max}$: 3430, 1710, 1670, 1640 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 214 (ε 8000), 259 (12 600) nm; $^1$Hmr δ: 1.21 (3H, d, $J_{7',8'}$ = 6.0 Hz, H-8'), 1.34 (3H, s, isopropylidene-Me), 1.43–2.03 (4H, m, 2(H-5')'s, 2(H-6')'s), 1.57 (3H, s, isopropylidene-Me), 2.45 (1H, bs, OH, exchanged in $D_2O$), 3.28 (3H, s, NMe), 3.64–4.61 (4H, H-3'–H-5', H-7'), 4.84 (1H, dd, $J_{2',3'}$ = 6.5 Hz, $J_{1',2'}$ = 2.0 Hz, H-2'), 5.58 (1H, d, H-1'), 5.72 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.19 (1H, d, H-6). *Anal.* calcd. for $C_{16}H_{24}N_2O_6$: C 56.46, H 7.11, N 8.23; found: C 56.06, H 7.42, N 7.97.

*1-[5,6,8-Trideoxy-2,3-O-isopropylidene-7-O-p-tolylsulfonyl-β-D-allo (and α-L-talo)-octofuranosyl]-3-methyluracil (14)*

To a solution of **13** (0.86 g, 2.5 mmol) in pyridine (4 mL) was added at 0°C *p*-toluenesulfonyl chloride (0.52 g, 2.8 mmol). The reaction mixture was kept at 0°C overnight to give only one product ($R_f$ 0.21, solvent *D*). The reaction mixture was poured with vigorous stirring into ice-water (40 mL). The aqueous mixture was extracted with dichloromethane; the dichloromethane extract was washed successively with cold 1 *N* sulfuric acid, saturated aqueous sodium hydrogen carbonate, and cold water. Evaporation of the dried ($MgSO_4$) solution afforded **14** as a chromatographically homogeneous syrup (1.07 g, 85%). An analytical sample was obtained by preparative tlc using toluene–acetone, 2:1 (v/v), as eluent; ir (film) $\nu_{max}$: 1710, 1670, 1630, 1360, 1180 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 227 (ε 12 000), 259 (10 500) nm; $^1$Hmr δ: 1.22 (3H, d, $J_{7',8'}$ = 6.0 Hz, H-8'), 1.32 (3H, s, isopropylidene-Me), 1.56 (3H, s, isopropylidene-Me), 1.65–1.84 (4H, m, 2(H-5')'s, 2(H-6')'s), 2.42 (3H, s, PhMe), 3.28 (3H, s, NMe), 3.82–4.76 (3H, H-3', H-4', H-7'), 4.80 (1H, dd, $J_{2',3'}$ = 6.5 Hz, $J_{1',2'}$ = 2.0 Hz, H-2'), 5.56 (1H, d, H-1'), 5.71 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.15 (1H, d, H-6), 7.17–7.78 (5H, m, aromatic H's). *Anal.* calcd. for $C_{23}H_{30}N_2O_8S$: C 55.86, H 6.11, N 5.67, S 6.48; found: C 55.49, H 6.34, N 5.48, S 6.19.

*1-[5,6,8-Trideoxy-7-O-p-tolylsulfonyl-β-D-allo (and α-L-talo)-octofuranosyl]-3-methyluracil (15)*

The product **14** (0.90 g, 1.8 mmol) was dissolved in cold 90% formic acid (5 mL) and the solution was kept at 0°C overnight. Cold water (15 mL) was added to the reaction mixture and evaporated. Addition of more water and evaporation were repeated to afford a pale yellow, solid residue which was fractionated on a column of silica gel by elution with toluene–acetone, 3:2 (v/v), to give **15** as a colorless glass (0.65 g, 78%) having $R_f$ 0.10 (solvent *C*); ir (film) $\nu_{max}$: 3420, 1710, 1660, 1630, 1360, 1180 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 226 (ε 13 000), 259 (12 600) nm; $^1$Hmr δ: 1.20 (3H, d, $J_{7',8'}$ = 6.0 Hz, H-8'), 1.69–1.89 (4H, m, 2(H-5')'s, 2(H-6')'s), 2.42 (3H, s, PhMe), 3.27 (3H, s, NMe), 3.87 (2H, bs, 2 OH), 4.02–4.78 (4H, H-2'–H-4', H-7'), 5.67 (1H, d, $J_{1',2'}$ = 3.5 Hz, H-1'), 5.77 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.15–7.81 (6H, H-6, aromatic H's).

*Cyclization of 15*

The product **15** (0.6 g, 1.3 mmol) in *N,N*-dimethylformamide

TABLE 1. Carbon-13 chemical-shift data[a] for 3′,7′-anhydrooctose nucleosides **16**, **17**, **35**, and **36**

| Compound | C-2 | C-4 | C-5 | C-6 | C-1′ | C-2′ | C-3′ | C-4′ | C-5′ | C-6′ | C-7′ | C-8′ | NMe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **16** | 150.8 | 162.7 | 101.6 | 137.6 | 94.2 | 75.6[b] | 80.3[b] | 75.9[b] | 31.5 | 29.5 | 73.5[b] | 21.0 | 27.6 |
| **17** | 150.9 | 162.8 | 101.7 | 137.6 | 93.8 | 72.7[b] | 73.9[b] | 76.2[b] | 25.0 | 27.9 | 70.9[b] | 17.5 | 27.6 |
| **35** | 150.6 | 162.3 | 102.3 | 138.6 | 93.3 | 74.2[b] | 79.8[b] | 79.1[b] | 28.5 | 25.5 | 76.2[b] | 65.0 | 27.6 |
| **36** | 150.7 | 162.3 | 102.3 | 138.4 | 92.3 | 72.5[b] | 74.6[b] | 76.2[b] | 23.4 | 26.1 | 73.8[b] | 60.9 | 27.6 |

[a]In ppm downfield from tetramethylsilane in chloroform-*d*.
[b]Assignments may be changed.

(10 mL) was vigorously stirred with sodium hydride (0.13 g, 5.2 mmol, 50% oil dispersion) at room temperature for 3 h, after which time tlc (solvent *C*) showed the absence of starting material. The reaction mixture was poured with stirring into ice-water (100 mL) and the mixture was extracted exhaustively with dichloromethane. The combined organic solutions were washed with a small amount of cold water, dried ($MgSO_4$), and concentrated to a syrup. Column chromatography on silica gel (toluene–acetone, 5:2 (v/v)) gave crystalline 1-(3,7-anhydro-5,6,8-trideoxy-β-D-*allo*-octofuranosyl)-3-methyluracil (**16**) (0.095 g, 25%). Recrystallization from toluene afforded white crystalline **16** having $R_f$ 0.30 (solvent *C*), mp 219.5–220°C; $[\alpha]_D$ +25.0° (*c* 0.14, $CHCl_3$); ir (KBr) $\nu_{max}$: 3410, 1700, 1650, 1620 $cm^{-1}$; uv $\lambda_{max}$ (EtOH): 214 (ε 7800), 261 (13 300) nm: $^1$Hmr δ: 1.26 (3H, d, $J_{7',8'}$ = 6.0 Hz, H-8′), 1.56–2.31 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 2.85 (1H, bs, OH, exchanged in $D_2O$), 3.07–4.29 (4H, H-2′–H-4′, H-7′), 3.30 (3H, s, NMe), 5.56 (1H, s, H-1′), 5.70 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.25 (1H, d, H-6). See Table 1 for $^{13}$Cmr data. Mass spectrum *m/e*: 282 ($M^+$, 14%), 264 ($M^+ - H_2O$, 6), 155 (b + 30, 42), 139 (264 − b, 20), 128 [$M^+$ − (b + CHO), 100], 127 (b + 2H, 62), 126 (b + H, 16), 98 (128 − CHOH, 29), 69 [(b + H) − MeNCO, 31]. *Anal.* calcd. for $C_{13}H_{18}N_2O_5$: C 55.31, H 6.43, N 9.92; found: C 55.22, H 6.39, N 9.73.

1-(3,7-Anhydro-5,6,8-trideoxy-α-L-*talo*-octofuranosyl)-3-methyluracil (**17**) was isolated as a colorless syrup (0.082 g, 21%) having $R_f$ 0.26; $[\alpha]_D$ +31.7° (*c* 0.30, $CHCl_3$); ir (film) $\nu_{max}$: 3410, 1700, 1650, 1620 $cm^{-1}$; uv $\lambda_{max}$ (EtOH): 214 (ε 7400), 261 (13 300) nm; $^1$Hmr δ: 1.32 (3H, d, $J_{7',8'}$ = 6.0 Hz, H-8′), 1.67–2.39 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 3.02 (1H, bs, OH, exchanged in $D_2O$), 3.28–4.51 (4H, H-2′–H-4′, H-7′), 3.30 (3H, s, NMe), 5.56 (1H, s, H-1′), 5.72 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.27 (1H, d, H-6). See Table 1 for $^{13}$Cmr data. Mass spectrum *m/e*: 282 ($M^+$, 10%), 264 ($M^+ - H_2O$, 5), 155 (b + 30, 50), 139 (264 − b, 18), 128 [$M^+$ − (b + CHO), 100], 127 (b + 2H, 65), 126 (b + H, 22), 98 (128 − CHOH, 32), 69 [(b + H) − MeNCO, 33]. *Anal.* calcd. for $C_{13}H_{18}N_2O_5$: C 55.31, H 6.43, N 9.92; found: C 55.46, H 6.30, N 9.80.

*[(Acetoxymethyl)carbonyl]methylenetriphenylphosphorane (8)*

To a cold solution of 1,3-dichloro-2-propanone (5 g, 39 mmol) (**36**) in acetone (150 mL) was added powdered lithium bromide (50 g) with vigorous stirring using a mechanical stirrer. The reaction mixture was stirred at 18–20°C for 3 days. Evaporation of the solvent gave a brownish solid which was partitioned between water and dichloromethane. The aqueous solution was extracted once more with a small amount of dichloromethane. The combined dichloromethane solutions were washed with cold water, dried ($MgSO_4$), and evaporated to afford crude 1,3-dibromo-2-propanone as a syrup.

A solution of the crude 1,3-dibromo-2-propanone in toluene (25 mL) was added dropwise to a stirred solution of triphenylphosphine (10.2 g, 39 mmol) in toluene (30 mL) at room temperature. Stirring was continued overnight at room temperature. The solid was collected by filtration, washed with toluene, and dried. To a stirred solution of the dried salt in 60% aqueous methanol (250 mL) was added an excess of powdered sodium carbonate. Stirring was continued for 30 min and more water (50 mL) was added to the reaction mixture. After being stirred for another 30 min, the solid was collected by filtration, washed thoroughly with water, and dried in a desiccator to afford crude (bromoacetyl)methylenetriphenylphosphorane (7.5 g) as a white solid having $R_f$ 0.18 (solvent *E*).

A mixture of the crude (bromoacetyl)methylenetriphenylphosphorane (7.5 g) and powdered sodium acetate (18 g) in *N,N*-dimethylformamide (200 mL) was stirred vigorously using a mechanical stirrer at 50°C for 3 days. The reaction mixture was poured into water and the mixture was extracted with dichloromethane a few times. The combined dichloromethane extracts were washed with water, dried ($MgSO_4$), and concentrated to a dark brownish solid. A solution of this solid in ethyl acetate was filtered through silica gel. Evaporation of the solvent afforded **8** as a yellow solid (4.1 g, 28% from 1,3-dichloro-2-propanone) having $R_f$ 0.16 (solvent *E*); $^1$Hmr δ: 2.12 (3H, s, OAc), 4.58 (2H, s, $COCH_2O$), 7.24–7.71 (16H, PCH, 15 aromatic H's). This material was suitable for use in the subsequent reaction.

*1-[(E)-8-O-Acetyl-5,6-dideoxy-2,3-O-isopropylidene-β-D-ribo-oct-5-eno-1,4-furanosid-7-ulosyl]-3-methyluracil (20)*

To a solution of **6** (1.79 g, 6.0 mmol) in dimethylsulfoxide (30 mL), stirred at room temperature under nitrogen, pyridine (0.48 mL), trifluoroacetic acid (0.23 mL), and *N,N′*-dicyclohexylcarbodiimide (3.72 g, 18 mmol) were added. After 18 h, the Wittig reagent **8** (2.94 g, 7.8 mmol) was added and stirring was continued for a further 24 h at room temperature. The product was isolated by the procedure which was used for **11** to give, after column chromatography (toluene–acetone, 6:1 (v/v)), **20** as a colorless syrup (1.7 g, 72%) having $R_f$ 0.36 (solvent *B*); ir (film) $\nu_{max}$: 1735, 1700, 1660, 1630 $cm^{-1}$; uv $\lambda_{max}$ (EtOH) 226 (ε 10 100), 255 (8500) nm; $^1$Hmr δ: 1.36 (3H, s, isopropylidene-Me), 1.57 (3H, s, isopropylidene-Me), 2.16 (3H, s, OAc), 3.28 (3H, s, NMe), 4.56–5.01 (4H, H-3′, H-4′, 2(H-8′)'s), 5.08 (1H, dd, $J_{2',3'}$ = 6.0 Hz, $J_{1',2'}$ = 1.2 Hz, H-2′), 5.56 (1H, d, H-1′), 5.76 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 6.27 (1H, d, $J_{5',6'}$ = 16.0 Hz, H-6′), 6.99 (1H, dd, $J_{4',5'}$ = 5.5 Hz, H-5′), 7.16 (1H, d, H-6).

*1-[(E)-8-O-Acetyl-5,6-dideoxy-2,3-O-isopropylidene-β-D-allo (and α-L-talo)-oct-5-enofuranosyl]-3-methyluracil (21)*

To a stirred solution of **20** (1.46 g, 3.7 mmol) in ethanol (20 mL) was added sodium borohydride (0.15 g, 3.9 mmol) at −20°C in the dark. Thin-layer chromatography (solvent *A*) showed that after 5 min the reaction mixture contained one major component ($R_f$ 0.51) but no starting material. The product was isolated by the procedure which was used for **12** to give, after column chromatography (toluene–acetone, 5:2 (v/v)), **21** as a colorless syrup (1.25 g, 85%); ir (film) $\nu_{max}$: 3430, 1735, 1710, 1660, 1630 $cm^{-1}$; uv $\lambda_{max}$ (EtOH): 212 (ε 6700), 259 (9100) nm; $^1$Hmr δ: 1.35 (3H, s, isopropylidene-Me), 1.57 (3H, s, isopropylidene-Me), 2.08 (3H, s, COMe), 3.29 (3H, s, NMe), 3.63–4.80

(5H, H-3′, H-4′, H-7′, 2(H-8′)'s), 4.99 (1H, dd, $J_{2',3'}$ = 6.0 Hz, $J_{1',2'}$ = 1.5 Hz, H-2′), 5.60 (1H, d, H-1′), 5.74 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 5.76–5.97 (2H, m, H-5′, H-6′), 7.21 (1H, d, H-6).

*1-[8-*O*-Acetyl-5,6-dideoxy-2,3-*O*-isopropylidene-*β*-*D*-allo (and α-*L*-talo)-octofuranosyl]-3-methyluracil (22)*

Catalytic hydrogenation of the allylic alcohols **21** (1.25 g, 3.4 mmol) was performed as described above for **12** and afforded, after column chromatography (toluene–acetone, 5:2 (v/v)), **22** as a glass (1.2 g, 90%) having $R_f$ 0.51 (solvent *A*); ir (film) $\nu_{max}$: 3430, 1730, 1710, 1665, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 212 (ε 7600), 259 (11 800) nm; $^1$Hmr δ: 1.36 (3H, s, isopropylidene-Me), 1.58 (3H, s, isopropylidene-Me), 1.48–1.95 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 2.08 (3H, s, OAc), 2.89 (1H, bs, OH, exchanged in $D_2O$), 3.30 (3H, s, NMe), 3.63–4.67 (5H, H-3′, H-4′, H-7′, 2(H-8′)'s), 4.94 (1H, dd, $J_{2',3'}$ = 6.0 Hz, $J_{1',2'}$ = 2.0 Hz, H-2′), 5.67 (1H, d, H-1′), 5.78 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.30 (1H, d, H-6). *Anal.* calcd. for $C_{18}H_{26}N_2O_8$: C 54.26, H 6.58, N 7.03; found: C 54.57, H 6.87, N 6.88.

*1-[8-*O*-Acetyl-5,6-dideoxy-2,3-*O*-isopropylidene-7-*O*-p-tolylsulfonyl-*β*-*D*-allo (and α-*L*-talo)-octofuranosyl]-3-methyluracil (23)*

To a solution of **22** (1.1 g, 2.8 mmol) in pyridine (5 mL) was added at 0°C *p*-toluenesulfonyl chloride (0.58 g, 3.1 mmol). The product was isolated by the procedure which was used for **14** to give, after column chromatography (toluene – ethyl acetate, 5:2 (v/v)), **23** as a white foam (1.27 g, 83%) having $R_f$ 0.51 (solvent *C*); ir (film) $\nu_{max}$: 1710, 1670, 1630, 1360, 1180 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 228 (ε 14 000), 259 (11 800) nm; $^1$Hmr δ: 1.35 (3H, s, isopropylidene-Me), 1.56 (3H, s, isopropylidene-Me), 1.64–1.98 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 1.90 (3H, s, OAc), 2.43 (3H, s, PhMe), 3.29 (3H, s, NMe), 3.78–4.92 (6H, H-2′–H-4′, H-7′ 2(H-8′)'s), 5.60 (1H, d, $J_{1',2'}$ = 2.0 Hz, H-1′), 5.73 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.15 (1H, d, H-6), 7.20–7.80 (5H, m, aromatic H's).

*1-[8-*O*-Acetyl-5,6-dideoxy-7-*O*-p-tolylsulfonyl-β-*D*-allo (and α-*L*-talo)-octofuranosyl]-3-methyluracil (24)*

Hydrolysis of **23** (0.18 g, 0.33 mmol) was performed as described above for **14** and afforded, after preparative tlc (toluene–acetone, 2:3 (v/v)), **24** as a glass (0.13 g, 75%) having $R_f$ 0.36 (solvent *A*); ir (film) $\nu_{max}$: 3410, 1710, 1670, 1630, 1360, 1180 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 227 (ε 13 000), 259 (12 000) nm; $^1$Hmr δ: 1.66–2.01 (4H, m, 2(H-5′)'s, 2(H-6′)s), 2.46 (3H, s, PhMe), 3.29 (3H, s, NMe), 3.60–5.11 (8H, H-2′–H-4, H-7′, 2(H-8′)'s, 2 OH's), 5.64 (1H, d, $J_{1',2'}$ = 3.5 Hz, H-1′), 5.82 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.27 (1H, d, H-6), 7.28–7.84 (5H, m, aromatic H's).

*Treatment of 24 with Sodium Hydride*

To a solution of **24** (0.101 g, 0.20 mmol) in dry 1,2-dimethoxyethane, stirred at room temperature under nitrogen, sodium hydride (0.014 g, 0.59 mmol) was added. Thin-layer chromatography (solvent *A*) showed that after 10 min the reaction mixture contained five new components ($R_f$ 0.27, 0.48, 0.51, 0.66, and 0.78) and the starting material ($R_f$ 0.36). After the reaction mixture had been stirred overnight tlc showed that three new components ($R_f$ 0, 0.08, and 0.23) had been formed and that two of the components formed earlier ($R_f$ 0.48 and 0.66) had almost disappeared. Cold water was added to the reaction mixture and the solution was carefully neutralized with 0.1 *N* hydrochloric acid. The neutralized solution was evaporated to dryness. The residue was extracted with methanol and the extract was evaporated to give a white solid which was fractionated on preparative tlc using toluene–acetone, 2:3 (v/v), as eluent. One ($R_f$ 0.27) of the major components was identified as being 1-[7,8-anhydro-5,6-dideoxy-β-D-*allo* (and α-L-*talo*)-octofuranosyl]-3-methyluracil (**25**) (0.015 g, 25%); ir (film) $\nu_{max}$: 3440, 1710, 1670, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 212 (ε 7800), 259 (13 000) nm; $^1$Hmr δ: 1.57–2.02 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 2.45–3.08 (3H, m, H-7′, 2(H-8′)'s), 3.27 (3H, s, NMe), 3.65–4.38 (5H, H-2′–H-4′, 2 OH's), 5.66 (1H, d, $J_{1',2'}$ = 3.5 Hz, H-1′), 5.75 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.34 (1H, d, H-6).

When **24** was treated with sodium methoxide in chloroform only one product was obtained (92%), which was identical to the material (**25**) isolated in the above experiment.

*1-[7,8-Anhydro-5,6-dideoxy-2,3-*O*-isopropylidene-β-*D*-allo (and α-*L*-talo)-octofuranosyl]-3-methyluracil (26)*

To a solution of **23** (0.94 g, 1.7 mmol) in chloroform (25 mL) was added sodium methoxide (0.114 g, 2.0 mmol) with stirring at 0°C. After the reaction mixture had been stirred overnight at 0°C, tlc (solvent *C*) showed that the reaction mixture contained only one component ($R_f$ 0.46) but no starting material. The reaction mixture was carefully neutralized with cold 1 *N* hydrochloric acid, diluted with water (15 mL), and extracted with dichloromethane (2 × 10 mL). The combined extracts were washed with water, dried ($MgSO_4$), and evaporated to give **26** as a syrup (0.57 g, 97%). An analytical sample was obtained by preparative tlc using toluene–acetone, 2:1 (v/v), as eluent; ir (film) $\nu_{max}$: 1710, 1670, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 212 (ε 7800), 259 (13 000) nm; $^1$Hmr δ: 1.28 (3H, s, isopropylidene-Me), 1.52 (3H, s, isopropylidene-Me), 1.45–1.97 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 2.38–2.99 (3H, m, H-7′, 2(H-8′)'s), 3.27 (3H, s, NMe), 3.81–4.63 (2H, m, H-3′, H-4′), 4.84 (1H, dd, $J_{2',3'}$ = 6.0 Hz, $J_{1',2'}$ = 2.0 Hz, H-2′), 5.56 (1H, d, H-1′), 5.70 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.17 (1H, d, H-6).

*1-[8-*O*-Allyl-5,6-dideoxy-2,3-*O*-isopropylidene-β-*D*-allo (and α-*L*-talo)-octofuranosyl]-3-methyluracil (27)*

To a stirred solution of **26** (0.57 g, 1.7 mmol) in allyl alcohol (7 mL) was added sodium alloxide (0.20 g, 2.5 mmol) at 0°C. The reaction mixture was stirred at 45–50°C. After 8 h tlc (solvent *C*) showed that the reaction mixture contained only one component ($R_f$ 0.29) but no starting material. The reaction mixture was carefully neutralized with cold 1 *N* hydrochloric acid. The neutralized solution was diluted with water (10 mL) and the solution was extracted with dichloromethane (3 × 10 mL). The combined extracts were washed with cold water, dried ($MgSO_4$), and concentrated to a brownish syrup which was purified by column chromatography (toluene–acetone, 3:1 (v/v)) to afford pure **27** as a colorless syrup (0.61 g, 88%); ir (film) $\nu_{max}$: 3480, 1710, 1660, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 211 (ε 6800), 259 (9300) nm; $^1$Hmr δ: 1.32 (3H, s, isopropylidene-Me), 1.50–1.90 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 1.54 (3H, s, isopropylidene-Me), 2.66 (1H, bs, OH), 3.27–4.64 (7H, H-3′, H-4′, H-7′, 2(H-8′)'s, 2 vinylic H's), 3.30 (3H, s, NMe), 4.85 (1H, dd, $J_{2',3'}$ = 6.0 Hz, $J_{1',2'}$ = 2.0 Hz, H-2′), 5.03–5.34 (2H, m, terminal vinylic H's) 5.58–6.39 (1H, m, vinylic H), 5.64 (1H, d, H-1′), 5.75 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.23 (1H, d, H-6).

*1-[8-*O*-Allyl-5,6-dideoxy-2,3-*O*-isopropylidene-7-*O*-p-tolylsulfonyl-β-*D*-allo (and α-*L*-talo)-octofuranosyl]-3-methyluracil (28)*

To a solution of **27** (0.58 g, 1.4 mmol) in pyridine (3 mL) was added at 0°C *p*-toluenesulfonyl chloride (0.33 g, 1.7 mmol). Thin-layer chromatography (solvent *C*) showed that after the reaction mixture had been kept overnight it contained only one component ($R_f$ 0.56) but no starting material. The product was isolated by the procedure which was used for **14** to give **28** as a syrup (0.75 g, 94%). An analytical sample was obtained by preparative tlc using toluene–acetone, 2:1 (v/v) as eluent; ir (film) $\nu_{max}$: 1710, 1670, 1630, 1360, 1180 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 227 (ε

15 000), 259 (13 500) nm; $^1$Hmr δ: 1.26 (3H, s, isopropylidene-Me), 1.48 (3H, s, isopropylidene-Me), 1.60–1.78 (4H, m, 2(H-5')'s, 2(H-6')'s), 2.45 (3H, s, PhMe), 3.23 (3H, s, NMe), 3.32–5.18 (10H, H-2'–H-4', H-7', 2(H-8')'s, 2 allylic H's, 2 terminal vinylic H's), 5.38–5.99 (1H, m, vinylic H), 5.54 (1H, d, $J_{1',2'}$ = 2.0 Hz, H-1'), 5.68 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.05–7.79 (6H, aromatic H's, H-6).

*1-[8-*O*-Allyl-5,6-dideoxy-7-*O*-p-tolylsulfonyl-*β*-D-allo (and α-L-talo)-octofuranosyl]-3-methyluracil (29)*

Deblocking of the isopropylidene groups of **28** (0.7 g, 1.2 mmol) was performed as described above for **14** and afforded, after column chromatography (toluene–acetone, 7:3 (v/v)), **29** as a colorless syrup (0.58 g, 89%) having $R_f$ 0.17 (solvent *C*); ir (film) $\nu_{max}$: 3430, 1710, 1660, 1355, 1180 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 227 (ε 15 500), 259 (13 500) nm; $^1$Hmr δ: 1.69–2.02 (4H, m, 2(H-5')'s, 2(H-6')'s), 2.44 (3H, s, PhMe), 3.30 (3H, s, NMe), 3.28–5.39 (10H, H-2'–H-4', H-7', 2(H-8')'s, 2 allylic H's, 2 terminal vinylic H's), 5.62 (1H, d, $J_{1',2'}$ = 3.5 Hz), 5.48–6.34 (1H, m, vinylic H), 5.76 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.08–7.83 (6H, H-6, 5 aromatic H's).

*1-[8-*O*-Allyl-3,7-anhydro-5,6-dideoxy-β-D-allo (and α-L-talo)-octofuranosyl]-3-methyluracil (30)*

Product **28** (0.57 g, 1.1 mmol) in 1,2-dimethoxyethane (20 mL) was stirred with sodium hydride (0.11 g, 4.4 mmol, 50% oil dispersion) at room temperature for 8 h. The reaction mixture was poured into ice-water (40 mL) and the mixture was exhaustively extracted with dichloromethane. The combined extracts were washed with a small amount of water, dried ($MgSO_4$), and concentrated to a syrup which was chromatographed on a column of silica gel (toluene–acetone, 5:2 (v/v)) to give **30** as a colorless syrup (0.22 g, 54%) having $R_f$ 0.49 (solvent *A*); ir (film) $\nu_{max}$: 3420, 1710, 1660, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 214 (ε 6400), 262 (9850) nm; $^1$Hmr δ: 1.55–2.05 (4H, m, 2(H-5')'s, 2(H-6')'s), 3.30 (3H, s, NMe), 3.14–4.40 (9H, H-2'–H-4', H-7', 2(H-8')'s, 2 allylic H's, OH), 5.02–5.39 (2H, m, 2 terminal vinylic H's), 5.65 (1H, s, H-1'), 5.59–6.23 (1H, m, vinylic H), 6.77 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.34 (1H, d, H-6).

*Isomerization of the Allyl Groups in 30 with $RhCl(PPh_3)_3$*

A mixture of **30** (210 mg, 0.56 mmol), 1,4-diazabicyclo[2.2.2]-octane (18 mg), and $RhCl(PPh_3)_3$ (52 mg, 0.056 mmol) in 60% aqueous ethanol was heated at reflux temperature. After 1.5 h tlc (solvent *A*) showed that the reaction mixture contained two components ($R_f$ 0.55, 0.58) but no starting material. The reaction mixture was filtered, and the filtrate was concentrated to half-volume and then partitioned between water and dichloromethane. The aqueous layer was further extracted with dichloromethane a few times. The dried ($K_2CO_3$) organic solution was concentrated to a brownish foam which was fractionated on a column of silica gel (toluene–acetone, 3:1 (v/v)) to give 1-[3,7-anhydro-5,6-dideoxy-8-*O*-(prop-1-enyl)-β-D-*allo*-octofuranosyl]-3-methyluracil (**31**) as a colorless syrup (94 mg, 45%) having $R_f$ 0.58, $[\alpha]_D$ +32.7° (*c* 0.26, $CH_2Cl_2$); ir (film) $\nu_{max}$: 3430, 1710, 1660, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 212 (ε 6500), 261 (12 500) nm; $^1$Hmr δ: 1.56 (3H, dd, $^1J$ = 6.5 Hz, $^2J$ = 1.5 Hz, allylic Me), 1.58–2.02 (4H, m, 2(H-5')'s, 2(H-6')'s), 3.15–5.01 (8H, H-2'–H-4', H-7', 2(H-8')'s, =CH, OH), 3.29 (3H, s, NMe), 5.61 (1H, s, H-1'), 5.71 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 5.86–6.30 (1H, m, =HCO), 7.30 (1H, d, H-6).

1-[3,7-Anhydro-5,6-dideoxy-8-*O*-(prop-1-enyl)-α-L-*talo*-octofuranosyl]-3-methyluracil (**32**) was isolated as a colorless syrup (88 mg, 42%) having $R_f$ 0.55; $[\alpha]_D$ +35.4° (*c* 0.26, $CH_2Cl_2$); ir (film) $\nu_{max}$: 3430, 1710, 1660, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 212 (ε 7000), 261 (12 500) nm; $^1$Hmr δ: 1.58 (3H, dd, $^1J$ = 6.5 Hz, $^2J$ = 1.5 Hz, allylic Me), 1.58–2.02 (4H, m, 2(H-5')'s, 2(H-6')'s), 3.19–4.94 (8H, H-2'–H-4', H-7', 2(H-8')'s, =CH, OH), 3.30 (3H, s, NMe), 5.62 (1H, s, H-1'), 5.76 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 5.91–6.32 (1H, m, =HCO), 7.38 (1H, d, H-6).

*1-(3,7-Anhydro-2-O-benzoyl-5,6-dideoxy-β-D-allo-octofuranosyl)-3-methyluracil (35)*

To a cooled solution of **31** (92 mg, 0.25 mmol) in pyridine (2 mL) was added benzoyl chloride (42 mg, 0.30 mmol). The reaction mixture was kept at room temperature for 30 min and then poured into cold water (20 mL), and the mixture was extracted with dichloromethane (2 × 20 mL). Concentration and then co-evaporation with toluene of the dried ($MgSO_4$) dichloromethane solution afforded crude 1-[3,7-anhydro-2-*O*-benzoyl-8-*O*-(prop-1-enyl)-β-D-*allo*-octofuranosyl]-3-methyluracil (**33**) as a colorless syrup having $R_f$ 0.72 (solvent *A*). To a solution of crude **33** in 60% aqueous methanol (8 mL) was added 0.1 *N* hydrochloric acid in 80% aqueous methanol (8 mL). The reaction mixture was stirred at room temperature for 8 h and then neutralized by addition of silver carbonate. The silver salts were removed by filtration. The filtrate was concentrated to half-volume and then extracted with dichloromethane several times. The dried ($MgSO_4$) organic solution was concentrated to a yellow solid which was fractionated by preparative tlc (toluene–acetone, 2:1 (v/v)) to afford **35** as a colorless syrup (87 mg, 88% from **31**) having $R_f$ 0.46 (solvent *C*); $[\alpha]_D$ +28.8° (*c* 0.07, $CH_2Cl_2$); ir (film) $\nu_{max}$: 3430, 1710, 1660, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 231 (ε 15 100), 258 (10 300) nm; $^1$Hmr δ: 1.54–1.88 (4H, m, 2(H-5')'s, 2(H-6')'s), 3.28 (3H, s, NMe), 3.52–3.86 (6H, H-3', H-4', H-7', 2(H-8')'s, OH), 5.62 (1H, d, $J_{2',3'}$ = 4.0 Hz, H-2'), 5.72 (1H, s, H-1'), 5.78 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.21–8.23 (6H, H-6, aromatic H's). See Table 1 for $^{13}$Cmr data.

*1-(3,7-Anhydro-2-O-benzoyl-5,6-dideoxy-α-L-talo-octofuranosyl)-3-methyluracil (36)*

Compound **32** (85 mg, 0.23 mmol) was benzoylated as described above for compound **31** to give crude 1-[3,7-anhydro-2-*O*-benzoyl-5,6-dideoxy-8-*O*-(prop-1-enyl)-α-L-*talo*-octofuranosyl]-3-methyluracil (**34**) as a colorless syrup having $R_f$ 0.72 (solvent *A*). Removal of the prop-1-enyl group of **34** was performed as described above for **33** to afford, after the preparative tlc (toluene–acetone, 2:1 (v/v)), **36** as a colorless syrup (80 mg, 88% from **32**) having $R_f$ 0.43 (solvent *C*); $[\alpha]_D$ +32.7° (*c* 0.09, $CH_2Cl_2$); ir (film) $\nu_{max}$: 3430, 1710, 1660, 1630 cm$^{-1}$; uv $\lambda_{max}$ (EtOH): 230 (ε 14 000), 258 (10 000) nm; $^1$Hmr δ: 1.75–1.96 (4H, m, 2(H-5')'s, 2(H-6')'s), 3.28 (3H, s, NMe), 3.66–4.15 (6H, H-3', H-4', H-7', 2(H-8')'s, OH), 5.62 (1H, d, $J_{2',3'}$ = 4.0 Hz, H-2'), 5.77 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 5.78 (1H, s, H-1'), 7.20–8.15 (6H, H-6, aromatic H's). See Table 1 for $^{13}$Cmr data.

*1-(3,7-Anhydro-5,6-dideoxy-β-D-allo-octofuranosyl)-3-methyluracil (37)*

To a solution of **35** (80 mg, 0.20 mmol) in methanol (2 mL) was added 1 *N* sodium methoxide in methanol (0.07 mL) at room temperature. The reaction was complete almost immediately. The reaction mixture was filtered through ion-exchange resin ($H^+$) and the resin was washed with a small amount of methanol. Evaporation of the methanol solution afforded a brownish residue which was purified by preparative tlc (ethyl acetate–acetone, 3:1 (v/v)) to give **37** as an amorphous solid (58 mg, 98%) having $R_f$ 0.63 (solvent *F*); $[\alpha]_D$ +21.2° (*c* 0.05, MeOH); ir (KBr) $\nu_{max}$: 3350, 1700, 1660, 1620 cm$^{-1}$; uv $\lambda_{max}$ (MeOH): 214 (ε 7500), 262 (12 800) nm; $^1$Hmr δ (DMSO-$d_6$): 1.66–2.12 (4H, m, 2(H-5')'s, 2(H-6')'s), 3.27 (3H, s, NMe), 3.11–4.28 (6H, H-2'–H-4', H-7', 2(H-8')'s), 5.72 (1H, s, H-1'), 5.80 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.66 (1H, d, H-6). *Anal.* calcd. for $C_{13}H_8N_2O_6$: C 52.35, H 6.08, N 9.39; found: C 52.39, H 6.23, N 9.47.

*1-(3,7-Anhydro-5,6-dideoxy-α-L-talo-octofuranosyl)-3-methyluracil (38)*

Compound **36** (29 mg, 0.072 mmol) was debenzoylated in a

manner similar to that used for compound **35** to afford, after preparative tlc (ethyl acetate – acetone, 3:1 (v/v)), **38** as an amorphous solid (21 mg, 98%) having $R_f$ 0.61 (solvent *F*); $[\alpha]_D$ +25.6° (*c* 0.06, MeOH); ir (film) $\nu_{max}$: 3350, 1700, 1650, 1620 $cm^{-1}$; uv $\lambda_{max}$ (MeOH): 214 (ε 7500), 262 (13 000) nm; $^1$Hmr δ (DMSO-$d_6$): 1.75–2.21 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 3.27 (3H, s, NMe), 3.18–4.23 (6H, H-2′–H-4′, H-7′, 2(H-8′)'s), 5.72 (1H, s, H-1′), 5.82 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.71 (1H, d, H-6). *Anal.* calcd. for $C_{13}H_{18}N_2O_6$: C 52.35, H 6.08, N 9.39; found: C 52.59, H 6.08, N 9.20.

*1-(3,7-Anhydro-5,6-dideoxy-*β*-D-*allo*-octofuranosyluronic acid)-3-methyluracil (39)*

A mixture of **37** (50 mg, 0.17 mmol) in water (5 mL) and 10% platinum-on-charcoal catalyst (13 mg) were placed in a 30-mL test tube. The pH of the solution was adjusted to ~8.5 by addition of saturated aqueous sodium hydrogen carbonate solution. Oxygen was vigorously bubbled through the reaction mixture to provide sufficient agitation. The temperature of the reaction mixture was maintained at 70°C by means of a water bath throughout the course of the reaction. Every 30 min the pH of the reaction mixture was checked and adjusted to 8.5. The reaction was complete in 3 h. The reaction mixture was filtered through Celite twice and the filtrate was washed with dichloromethane. The aqueous solution was eluted through ion-exchange resin ($H^+$) and then freeze-dried to give a brownish foam which was carefully purified by preparative tlc (*n*-butanol – methanol–water, 8:1:1 (v/v)) to afford **39** as a colorless glass (39 mg, 74%) having $R_f$ 0.18 (solvent *G*); $[\alpha]_D$ +14.4° (*c* 0.3, 0.1 *N* aqueous sodium hydroxide); ir (film) $\nu_{max}$: 3420, 1710, 1660, 1620 $cm^{-1}$; uv $\lambda_{max}$ ($H_2O$): 213 (ε 7800), 262 (13 500) nm; $^1$Hmr δ ($D_2O$): 1.78–2.29 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 2.97–4.45 (4H, H-2′–H-4′, H-7′), 3.26 (3H, s, NMe), 5.71 (1H, s, H-1′), 5.88 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.62 (1H, d, H-6). *Anal.* calcd. for $C_{13}H_{16}N_2O_7$: C 50.00, H 5.17, N 8.97; found: C 50.13, H 5.23, N 9.11.

*3-Methyl-1-(methyl 3,7-anhydro-5,6-dideoxy-*β*-D-*allo*-octofuranosyluronate)uracil (40)*

To a stirred solution of compound **39** (37 mg, 0.12 mmol) in methanol (1 mL) was added 5% hydrogen chloride in methanol (2 mL) at °C. After 2 h, the reaction mixture was neutralized with silver carbonate. Silver salts were removed by filtration and the filtrate was concentrated to a pale yellow syrup which was purified by preparative tlc (toluene–acetone, 1:1 (v/v)) to afford **40** as a colorless syrup (31 mg, 81%) having $R_f$ 0.38 (solvent *A*); $[\alpha]_D$ +25.7° (*c* 0.05, $CHCl_3$); ir (film) $\nu_{max}$: 3430, 1710, 1660, 1630 $cm^{-1}$; uv $\lambda_{max}$ (MeOH): 214 (ε 7500), 262 (14 000) nm; $^1$Hmr δ: 1.75–2.23 (4H, m, 2(H-5′)'s, 2(H-6′)'s), 3.27 (3H, s, NMe), 3.75 (3H, s, COOMe), 3.02–4.51 (4H, H-2′–H-4′, H-7′), 5.72 (1H, s, H-1′), 5.86 (1H, d, $J_{5,6}$ = 8.0 Hz, H-5), 7.62 (1H, d, H-6).

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1. J. M. Webber. Adv. Carbohydr. Chem. **17**, 15 (1962); C. S. Hudson. Adv. Carbohydr. Chem. **1**, 1 (1945).
2. K. Freudenberg. Adv. Carbohydr. Chem. **21**, 1 (1960).
3. H. Paulsen, K. Roden, V. Sinnwell, and W. Koebernick. Angew. Chem. Int. Ed. Engl. **15**, 439 (1976); H. Paulsen. Pure Appl. Chem. **49**, 1169 (1977); J. A. Secrist III and S.-R. Wu. J. Org. Chem. **44**, 1434 (1979).
4. R. R. Herr and G. Slomp. J. Am. Chem. Soc. **89**, 2444 (1967); W. Schroeder, B. Bannister, and H. Hoeksema. J. Am. Chem. Soc. **89**, 2448 (1967); G. Slomp and F. A. Mackeller. J. Am. Chem. Soc. **89**, 2454 (1967); B. J. Margerlein, R. D. Birkenmeyer, R. R. Herr, and F. Kagan. J. Am. Chem. Soc. **89**, 2459 (1967).
5. H. Hoeksema. J. Am. Chem. Soc. **86**, 4224 (1964); H. Hoeksema and J. W. Hinman. J. Am. Chem. Soc. **86**, 4979 (1964); H. Hoeksema. J. Am. Chem. Soc. **90**, 755 (1968).
6. S. O'Connor, L. K. T. Lam, N. D. Jones, and M. O. Chaney. J. Org. Chem. **41**, 2087 (1976).
7. D. E. Dorman, J. W. Paschal, and K. E. Merkel. J. Am. Chem. Soc. **98**, 6885 (1976).
8. K. Sakata, A. Sakurai, and S. Tamura. Tetrahedron Lett. 4327 (1974); Agric. Biol. Chem. **39**, 885 (1975); Tetrahedron Lett. 3191 (1975); Agric. Biol. Chem. **40**, 1993 (1976).
9. S. Harada, E. Mizuta, and T. Kishi. J. Am. Chem. Soc. **100**, 4895 (1978).
10. T. Ito, Y. Kodama, K. Kawamura, K. Suzuki, A. Takatsuki, and G. Tamura. Agric. Biol. Chem. **41**, 2303 (1977).
11. B. C. Das, J. D. Defaye, and K. Uchida. Carbohydr. Res. **22**, 293 (1972); K. Uchida and B. C. Das. Biochimie, **55**, 635 (1973); K. Uchida. Agric. Biol. Chem. **40**, 395 (1976); K. Uchida, E. Breitmair, and W. A. Koenig. Tetrahedron, **31**, 2315 (1975); S. Ennifar, B. C. Das, S. M. Nash, and R. Nagarajan. J. Chem. Soc. Chem. Commun. 41 (1977); M. Vuilhorgne, S. Ennifar, B. C. Das, J. W. Paschal, R. Nagarajan, E. W. Hagaman, and E. Wenkert. J. Org. Chem. **42**, 3289 (1977).
12. G. B. Howarth, D. G. Lance, W. A. Szarek, and J. K. N. Jones. Can. J. Chem. **47**, 75 (1969); D. G. Lance and W. A. Szarek. Carbohydr. Res. **10**, 306 (1969); G. B. Howarth, W. A. Szarek, and J. K. N. Jones. Chem. Commun. 1339 (1969); D. G. Lance, W. A. Szarek, J. K. N. Jones, and G. B. Howarth. Can. J. Chem. **47**, 2871 (1969).
13. G. B. Howarth, W. A. Szarek, and J. K. N. Jones. J. Chem. Soc. C, 2218 (1970); G. R. Woolard, E. B. Rathbone, W. A. Szarek, and J. K. N. Jones. J. Chem. Soc. Perkin Trans. I, 950 (1976).
14. H. C. Jarrell and W. A. Szarek. Carbohydr. Res. **67**, 43 (1978); Can. J. Chem. **56**, 144 (1978); **57**, 924 (1979).
15. K. Sakata, A. Sakurai, and S. Tamura. Agric. Biol. Chem. **37**, 697 (1973).
16. K. Sakata, A. Sakurai, and S. Tamura. Agric. Biol. Chem. **38**, 1883 (1974).
17. K. Isono, P. F. Crain, and J. A. McCloskey. J. Am. Chem. Soc. **97**, 943 (1975).
18. T. Azuma, K. Isono, P. F. Crain, and J. A. McCloskey. Tetrahedron Lett. 1687 (1976).
19. T. Azuma and K. Isono. Chem. Pharm. Bull. **25**, 3347 (1977).
20. T. Sato, K. Hirasawa, J. Uzawa, T. Inaba, and K. Isono. Tetrahedron Lett. 3441 (1979).
21. K. Anzai and T. Saita. J. Chem. Soc. Chem. Commun. 681 (1976); Bull. Chem. Soc. Jpn. **50**, 169 (1977).
22. K. Sakata and J. Uzawa. Agric. Biol. Chem. **41**, 413 (1977); K. Sakata, J. Uzawa, and A. Sakurai. Org. Magn. Reson. **10**, 230 (1977).
23. N. K. Kochetkov, E. I. Budowsky, and V. N. Shibaev. *In* Synthetic procedures in nucleic acid chemistry. Vol. 1. *Edited by* W. W. Zorbach and R. S. Tipson. Interscience, New York, NY. 1968. p. 498.
24. Y. A. Zhdanov, G. N. Dorofeenko, and L. A. Uslova. Zh. Obshch. Khim. **35**, 181 (1965); F. Ramierz, A. V. Domvrovsky, and M. I. Shevchuk. J. Org. Chem. **22**, 41 (1957).

25. C. D. JARDETZKY. J. Am. Chem. Soc. **84**, 62 (1962); F. E. HRUSKA, A. A. GREY, and I. C. P. SMITH. J. Am. Chem. Soc. **92**, 4088 (1970); M. KAINOSHO and K. AJISAKA. J. Am. Chem. Soc. **97**, 6839 (1975).
26. K. BIEMANN and J. A. MCCLOSKEY. J. Am. Chem. Soc. **84**, 2005 (1962).
27. A. M. LAWSON, R. N. STILLWALL, M. M. TACKER, K. TSUBOYAMA, and J. A. MCCLOSKEY. J. Am. Chem. Soc. **93**, 1014 (1971).
28. D. K. DALLING and D. M. GRANT. J. Am. Chem. Soc. **89**, 6612 (1967); A. J. JONES, E. L. ELIEL, D. M. GRANT, M. C. KNOEBER, and W. F. BAILEY. J. Am. Chem. Soc. **93**, 4772 (1971).
29. F. JOHNSON, W. D. GUROWITZ, and N. A. STARKOVSKY. Tetrahedron Lett. 1173 (1962); F. JOHNSON, N. A. STARKOVSKY, and W. D. GUROWITZ. J. Am. Chem. Soc. **87**, 3492 (1965); E. L. ELIEL and M. C. KNOEBER. J. Am. Chem. Soc. **90**, 3444 (1968); J. L. JUNGNICKEL and C. A. REILLY. J. Mol. Spectrosc. **16**, 135 (1965); M. BARON and D. P. HOLLIS. Recl. Trav. Chim. Pays-Bas, **83**, 391 (1964).
30. D. E. BERGSTROM and W. C. AGOSTA. Tetrahedron Lett. 1087 (1974).
31. Y. A. ZHDANOV and L. A. USLOVA. Zh. Obshch. Khim. **36**, 1211 (1966).
32. J. CUNNINGHAM, R. GIGG, and C. D. WARREN. Tetrahedron Lett. 1191 (1964); J. GIGG and R. GIGG. J. Chem. Soc. C, 82 (1966); R. GIGG and C. D. WARREN. J. Chem. Soc. 2205 (1965).
33. E. J. COREY and J. W. SUGGS. J. Org. Chem. **38**, 3224 (1973).
34. R. GIGG and C. D. WARREN. J. Chem. Soc. C, 1903 (1968).
35. R. S. TIPSON. *In* Synthetic procedures in nucleic acid chemistry. Vol. 1. *Edited by* W. W. Zorbach and R. S. Tipson. Interscience, New York, NY. 1968. p. 431.
36. J. B. CONANT and O. R. QUAYLE. Org. Synth. Coll. Vol. **1**, 211 (1932).