Carbohydrate Research, 229 (1992) 293–305
Elsevier Science Publishers B.V., Amsterdam

Synthesis of derivatives of methyl 3-deoxy-3-*C*-formyl-α-D-*arabino*-pentofuranoside

Sylvie Benefice-Malouet, Paul L. Coe and Richard T. Walker

School of Chemistry, Birmingham University, P.O. Box 363, Birmingham B15 2TT (United Kingdom)

(Received May 22nd, 1991; accepted October 31st, 1991)

ABSTRACT

Methyl 2,3-anhydro-α-D-lyxofuranoside and some 5-substituted derivatives react with 2-lithio-1,3-dithiane and phenylthiomethyl-lithium at both positions of the epoxide ring, but mainly at C-3. The ratio of the adducts is affected by the nature of the 5-substituent. Appropriate desulphuration reactions of the dithioacetal and sulphide functions in the adducts gave derivatives of methyl 3-deoxy-3-*C*-formyl-α-D-*arabino*-pentofuranoside.

INTRODUCTION

During the past decade, many nucleoside analogues have been shown to have antiviral activity and the synthesis of branched-chain sugars, precursors of these molecules, has become of considerable interest. Nucleoside analogues that contain a 3′-*C*-hydroxymethyl or a 3′-*C*-fluoromethyl group have remarkable activity against the *Varicella zoster* virus[1]. For this reason and also because of its potential use as a precursor for other compounds, the synthesis of a 3-*C*-formyl-arabinofuranoside has been investigated.

The synthesis of chain-extended sugars with an aldehyde group in the side chain has been a problem in carbohydrate chemistry and probably explains why this kind of compound has not been reported hitherto. We now report two syntheses of 5-protected methyl 3-deoxy-3-*C*-formyl-α-D-*arabino*-pentofuranoside (**1**) starting from methyl 2,3-anhydro-α-D-lyxofuranoside (**2**).

RESULTS AND DISCUSSION

2,3-Anhydropentofuranosides can undergo many reactions[2] through nucleophilic scission of the epoxide ring. However, the synthesis of chain-extended sugars

Correspondence to (present address): Dr. S. Benefice-Malouet, Laboratoire "Hétérochimie et Aminoacides", Associé au C.N.R.S. (U.R.A. 1097), Université de Montpellier II, Place E. Bataillon, 34095 Montpellier 05, France.

with a carbonyl group in the side chain has been confined to pyranosides[3] and some particular xylofuranosides[4].

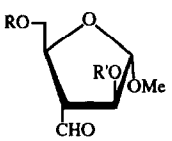
In order to obtain **1**, the epoxide ring opening of **2** was investigated. The epoxide **2** has been prepared either from xylose[5] or arabinose[6]. The former synthesis involved five steps and gave a low yield of an α,β-mixture, whereas the latter synthesis involved three steps and gave 66% of crystalline **1**.

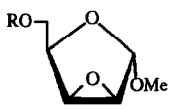
Dithianes have been used extensively in organic chemistry following the discovery[7,8] of their metallation and subsequent reactions with electrophiles. It was noted that epoxides react very slowly with dithiane anions and that 2-lithio-1,3-dithiane (**3**) was suitable for the introduction of the formyl group (after hydrolysis) into organic molecules having electrophilic carbon atoms. The extension of this reaction into carbohydrate chemistry[9] has provided a versatile means of extending or branching chains. Chain-extension of sugars can also be achieved by reaction of 4,5-dihydro-2-lithio-5-methyl-1,3,5-dithiazine with sugar epoxides[10]. The desulphuration of these products proceeds under milder conditions than for the corresponding 1,3-dithiane adducts. However, the stability of this organolithium derivative required the use of low temperatures (−78°C), when it is then no longer sufficiently activated to react with **2**. Investigation of **2** showed that the epoxide ring opening would not occur at < 0°C.

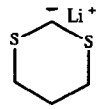
Corey and Seebach[11] also described another series of organolithium derivatives similar to phenylthiomethyl-lithium (**4**) and the applications in synthesis of these reagents at room temperature or at higher temperatures.

Thus, the synthesis of **1** involved (*a*) the metallation of 1,3-dithiane and thioanisole with butyl-lithium in tetrahydrofuran, (*b*) the reaction of the lithio derivatives **3** and **4** with epoxide **2** and its 5-protected derivatives **5**–**7**, and (*c*) the hydrolysis of the products to give the carbonyl compounds.

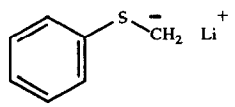
Initially, HO-5 in **2** was protected variously with a trityl, *tert*-butyldiphenylsilyl, or benzyl group. Thus, reaction of **2** in dry pyridine with trityl chloride or *tert*-butyldiphenylsilyl chloride gave 90% of the corresponding 5-*O*-trityl (**5**) or 5-*O*-*tert*-butyldiphenylsilyl (**6**) derivative. Reaction of **2** in dry *N*,*N*-dimethylformamide with benzyl bromide in the presence of an equimolar amount of sodium hydride gave 85% of the 5-*O*-benzyl derivative **7**.







3



4

1a R = Bn, R' = H
1b R = R' = Bz
1c R = ^{t}BuPh$_2$Si, R' = Bz
1d R = Bn, R' = Bz

2 R = H
5 R = Tr
6 R = ^{t}BuPh$_2$Si
7 R = Bn

Treatment of 1,3-dithiane in tetrahydrofuran at −20° with an equimolar amount of butyl-lithium gave the lithium derivative **3** and treatment[11] of thioanisole in

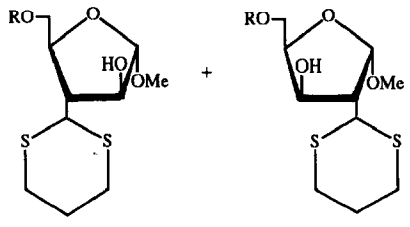
tetrahydrofuran at 0° with equimolar amounts of butyl-lithium and 1,4-diazabicyclo[2.2.2]octane[12] gave the lithium derivative **4**.

The epoxides **2** and **5–7** were each treated with the lithium derivatives **3** and **4**. Thus, in reactions with **3**, **2** gave 94% of **8** + **9** (94:6), **5** gave 80.2% of **10** + **11** (66:34), **6** gave 85% of **12** + **13** (68:32), and **7** gave 86% of **14** + **15** (87:13). In reactions with **4**, **2** gave 82% of **16** + **17** (95:5), **5** gave 69% of **18** + **19** (60:40), **6** gave 74% of **20** + **21** (63:38), and **7** gave 85% of **22** + **23** (72:28). The ratios were based on ^{1}H-NMR data.

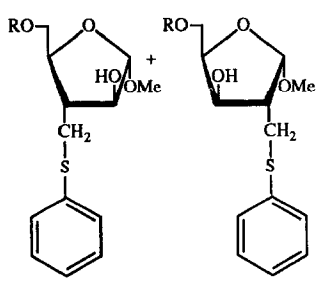
Nucleophilic attack occurred at both carbon atoms of the epoxide ring and the bulk of the 5-substituent affected the regioselectivity. For **2**, with HO-5 unprotected, attack occurred mainly at C-3 in accord with literature data[2], the only exception being the reaction of **3** with methyl 2,3-anhydro-5-*O*-benzoyl-lyxofuranoside[13], which gave mainly the C-3 adduct, but in low yield. Reaction occurred mainly at C-3 in **5–7** but the regioselectivity was less than that for **2**. Similar regioselectivity has been observed with substituted pyranosides[14] and β-nucleosides[1,15].

Treatment of the major isomers **10**, **12**, **14**, **18**, **20**, and **22** with 1 mol of benzoyl bromide and sodium hydride in *N*,*N*-dimethylformamide gave the corresponding 2-benzoates (**25–27** and **29–31**) in yields of 40–60%. Compounds **8** and **16** each gave some 2,5-dibenzoates (**24** 10.6% and **28** 8.3%, respectively), but the major products were the corresponding pyranoside 2-benzoates. Indeed, this acid-catalysed isomerisation usually occurs with 5-unprotected furanosides.

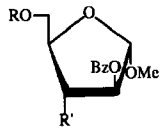
Cleavage of the thioacetal groups in **8**, **10**, **12**, and **14** and in the corresponding 2-benzoates **24–27** was investigated using mercuric oxide[16], *N*-bromosuccinimide[17], and boron trifluoride etherate[18]. Only the last method proved to be useful, but gave the desired 3-*C*-formylfuranoside derivatives (**1a**, **1b**, **1c**, and **1d**), in yields of ~ 80%, only from the benzylated and benzoylated compounds **14**, **27**, and **24**. The other substrates gave mainly pyranoside derivatives due to loss of trityl and

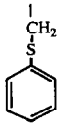


	R	
8	H	**9**
10	Tr	**11**
12	^{t}BuPh$_2$Si	**13**
14	Bn	**15**



	R	
16	H	**17**
18	Tr	**19**
20	^{t}BuPh$_2$Si	**21**
22	Bn	**23**



R'	R		%
	Bz	**24**	10.6
	Tr	**25**	42.0
	$^{t}BuPh_2Si$	**26**	42.0
	Bn	**27**	66.0
	Bz	**28**	8.3
	Tr	**29**	40.5
	$^{t}BuPh_2Si$	**30**	48.0
	Bn	**31**	58.0

tert-butyldiphenylsilyl groups under the acidic conditions, and subsequent furanoside–pyranoside rearrangement.

Desulphuration of the thioanisole adducts was investigated using the 2-*O*-benzoyl-5-*O*-benzyl derivative **31** and the 2,5-di-*O*-benzoyl derivative **28** by periodate oxidation in aqueous methanol to give sulphoxides, followed by Pummerer rearrangement[19] using trifluoroacetic anhydride–2,4,6-trimethylpyridine–acetonitrile. The products were the expected 3-*C*-formylarabinofuranosides **1b** and **1d**, respectively, in yields of 69%.

EXPERIMENTAL

General methods. — Melting points were determined using a Gallenkamp melting-point apparatus and are uncorrected. ^{1}H-NMR spectra were recorded with a Jeol FX 90 Q (90 MHz) or GX 270 (270 MHz) spectrometer on solutions in $CDCl_3$ (internal Me_4Si). FAB-mass spectra were obtained with a Kratos MS 80 mass spectrometer from samples dissolved in Me_2SO with 3-nitrobenzyl alcohol as the matrix; sodium chloride was added to give enhanced peaks, as necessary. Optical rotations were determined with a Perkin–Elmer 241 polarimeter. TLC was performed on Silica Gel 60 F_{254} (Merck), with detection using UV light (254 nm) or by charring with H_2SO_4. Column chromatography was performed on Silica Gel 60 (230–400 mesh, Merck). Flasks and stirring bars used for the generation and reactions of lithiodithiane and phenylthiomethyl-lithium were dried for ~ 12 h at 120° and then allowed to cool in a desiccator over P_2O_5. Tetrahydrofuran was heated under reflux over sodium in the presence of benzophenone until a deep blue colour had developed, then distilled, and stored over molecular sieves 4A. Pyridine was heated under reflux over calcium hydride, then distilled, and stored over molecular sieves. *N*,*N*-Dimethylformamide was stirred overnight with P_2O_5,

filtered, and distilled from fresh P_2O_5 under reduced pressure. Sugars were dried overnight under high vacuum over phosphorus pentaoxide.

*Methyl 2,3-anhydro-5-*O*-trityl-α-*D*-lyxofuranoside* (**5**). — To a solution of dry methyl 2,3-anhydro-α-D-lyxofuranoside[5] (**2**; 7.3 g, 50 mmol) in dry pyridine (120 mL) was added dry trityl chloride (16.7 g, 60 mmol). The mixture was stirred with the exclusion of moisture, at room temperature for 2 days, then cooled, poured with vigorous stirring into ice–water (1 L), and filtered. A solution of the gummy residue in ethyl acetate was washed several times with water, dried ($MgSO_4$), and filtered, and the solvent was evaporated. A solution of the residue in acetone–EtOH (1 : 1) was decolourised with charcoal, filtered, and concentrated to dryness in vacuo, and EtOH was evaporated from the residue. Flash-column chromatography (CH_2Cl_2–hexane, 8.5 : 1.5) on silica gel (Merck, 7734) then gave **5** (17.4 g, 90%). Recrystallisation from EtOH gave a product with mp 98–100°, $[\alpha]_D^{20}$ + 3.2° (*c* 1, chloroform). ^{1}H-NMR data: δ 3.32 (m, 2 H, OCH_2), 3.38 (s, 3 H, OMe), 3.65 (d, 1 H, $J_{2,3}$ 3 Hz, H-3), 3.88 (d, 1 H, H-2), 4.17 (m, 1 H, H-4), 4.88 (s, 1 H, H-1), 7.20–7.47 (m, 15 H, 3 Ph). Mass spectrum: *m/z* 388 (0.4%, M^+), 411 [100, $(M + Na)^+$], 243 (0.4, Tr^+).

Anal. Calcd for $C_{25}H_{24}O_4$: C, 77.34; H, 6.18. Found: C, 77.30; H, 6.10.

*Methyl 2,3-anhydro-5-*O*-*tert*-butyldiphenylsilyl-α-*D*-lyxofuranoside* (**6**). — To a solution of dry **2** (7.3 g, 50 mmol) in anhydrous pyridine (120 mL) was added *tert*-butylchlorodiphenylsilane (16.5 g, 15.61 mL, 60 mmol) dropwise. The mixture was stirred overnight at room temperature with the exclusion of moisture, water (25 mL) was added, and the clear solution was stirred for 30 min, then concentrated under high vacuum. Repeated trituration of the residue with water gave a colourless gum. Column chromatography (CH_2Cl_2–hexane 8.5 : 1.5) on silica gel (Merck, 9385) then gave amorphous **6** (17.3 g, 90%), $[\alpha]_D^{20}$ + 4.6° (*c*, 1, tetrahydrofuran). ^{1}H-NMR data: δ 1.08 (s, 9 H, ^{t}Bu), 3.39 (s, 3 H, OMe), 3.66 (d, 1 H, $J_{2,3}$ 3 Hz, H-3), 3.77 (d, 1 H, H-2), 3.85 (s, 2 H, OCH_2), 4.17 (m, 1 H, H-4), 4.88 (s, 1 H, H-1), 7.31–7.78 (m, 10 H, 2 Ph). Mass spectrum: *m/z* 384 (0.3%, M^+), 383 [0.25, $(M - H)^+$], 353 [0.3, $(M\text{-}OMe)^+$], 327 [100, $(M - {}^tBu)^+$].

Anal. Calcd for $C_{22}H_{28}O_4Si$: C, 68.76; H, 7.29. Found: C, 68.66; H, 7.20.

*Methyl 2,3-anhydro-5-*O*-benzyl-α-*D*-lyxofuranoside* (**7**). — To a stirred and cooled (ice-bath) solution of **2** (7.3 g, 50 mmol) in dry *N*,*N*-dimethylformamide (25 mL) were added sodium hydride (50% suspension in oil; 2.88 g, 60 mmol) and benzyl bromide (7.14 mL, 10.26 g, 60 mmol). After 4 h at room temperature, the reaction was complete, as indicated by TLC (ethyl acetate–hexane, 9 : 1). The mixture was poured into ice–water and extracted with ethyl acetate, the extract was washed with water, then dried ($MgSO_4$), and the solvent was evaporated. Flash-column chromatography (ethyl acetate–hexane, 9 : 1) of the syrupy residue gave amorphous **7** (10 g, 85%), $[\alpha]_D^{20}$ + 23° (*c* 5.8, chloroform). ^{1}H-NMR data: δ 3.38 (s, 3 H, OMe), 3.62 (d, 1 H, $J_{2,3}$ 3 Hz, H-3), 3.69 (s, 2 H, OCH_2), 3.76 (d, 1 H, H-2), 4.22 (m, 1 H, H-4), 4.58 (s, 2 H, $PhCH_2O$), 4.94 (s, 1 H, H-1), 7.32 (s, 5 H, Ph). Mass spectrum: *m/z* 236 (0.65%, M^+), 205 [0.28, $(M - OMe)^+$], 115 [0.45, $(M - BnOCH_2)^+$].

Anal. Calcd for $C_{13}H_{16}O_4$: C, 66.13; H, 6.78. Found: C, 66.00; H, 6.77.

General procedure for reactions with 2-lithio-1,3-dithiane. — To a solution of 1,3-dithiane (6 g, 50 mmol) in dry tetrahydrofuran (64 mL) at −20°, under dry nitrogen, was added butyl-lithium (1.6 M in hexane; 34.4 mL, 55 mmol) during 3 min using a syringe and septum cap with stirring. After 2.5 h, the clear, pale-yellow solution was warmed to room temperature, and a solution of **2**, **5**, **6**, or **7** (10 mmol) in dry tetrahydrofuran (20 mL) was added dropwise with vigorous stirring. After 3 h, TLC (CH_2Cl_2–hexane, 8.5 : 1.5) indicated no remaining starting material and a more polar product. The mixture was poured into water (250 mL), neutralised with M HCl, and extracted twice with ethyl acetate, the combined extracts were dried ($MgSO_4$) and filtered, and the solvent was evaporated. Column chromatography (CH_2Cl_2–hexane, 8.5 : 1.5) of the residue gave a mixture of two isomers as an orange gum. Column chromatography (ethyl acetate–hexane, 9 : 1) then gave the C-2 adduct first and finally the C-3 adduct, each isolated as a gum. The following compounds were prepared in this manner.

*Methyl 3-deoxy-3-(1,3-dithian-2-yl)-α-*D-arabino-*pentofuranoside* (**8**). — Prepared from **2**, **8** (88%) had $[\alpha]_D^{20}$ + 18° (*c* 1, chloroform). ^{1}H-NMR data: δ 2.05 (m, 2 H, CH_2CH_2), 2.90 (m, 5 H, H-3 and 2 SCH_2), 3.38 (s, 3 H, OMe), 3.89 (t, 2 H, $J_{4,5}$ 3 Hz, OCH_2), 4.00 (d, 1 H, $J_{CH,H-3}$ 7 Hz, SCHS), 4.29 (m, 1 H, H-2), 4.38 (m, 1 H, H-4), 4.69 (m, 2 H, 2 OH), 4.86 (s, 1 H, H-1). Mass spectrum: *m/z* 266 (0.4%, M^+), 249 [0.3, $(M - OH)^+$], 235 [0.3, $(M - OMe)^+$], 218 [0.4, $(M - OMe - OH)^+$].

Anal. Calcd for $C_{10}H_{18}O_4S_2$: C, 45.09; H, 6.81. Found: C, 45.12; H, 6.86.

*Methyl 2-deoxy-2-(1,3-dithian-2-yl)-α-*D-xylo-*pentofuranoside* (**9**). — Prepared from **2**, **9** (5.6%) had $[\alpha]_D^{20}$ + 26° (*c* 1, chloroform). ^{1}H-NMR data: δ 2.05 (m, 2 H, CH_2CH_2), 2.90 (m, 4 H, 2 SCH_2), 3.0 (m, 1 H, H-2), 3.38 (s, 3 H, OMe), 3.89 (m, 3 H, OCH_2 and H-3), 4.0 (d, 1 H, $J_{SCH,H-2}$ 7 Hz, SCHS), 4.50 (m, 1 H, H-4), 4.60 (m, 2 H, 2 OH), 4.98 (d, 1 H, $J_{1,2}$ 13 Hz, H-1). Mass spectrum: *m/z* 266 (0.4%, M^+), 249 [0.3, $(M - OH)^+$], 235 [0.3, $(M - OMe)^+$], 218 [0.4, $(M - OMe - OH)^+$].

Anal. Calcd for $C_{10}H_{18}O_4S_2$: C, 45.09; H, 6.81. Found: C, 45.14; H, 6.83.

*Methyl 3-deoxy-3-(1,3-dithian-2-yl)-5-*O*-trityl-α-*D-arabino-*pentofuranoside* (**10**). — Prepared from **5**, **10** (53%) had $[\alpha]_D^{20}$ + 13° (*c* 1, chloroform). ^{1}H-NMR data: δ 2.05 (m, 2 H, CH_2CH_2), 2.83 (m, 4 H, 2 SCH_2), 3.18 (m, 1 H, H-3), 3.45 (s, 3 H, OMe), 3.70 (d, 2 H, $J_{4,5}$ 2.7 Hz, OCH_2), 4.30 (d, 1 H, $J_{CH,H-3}$ 7 Hz, SCH), 4.61 (s, 1 H, OH), 4.72 (m, 1 H, H-2), 5.15 (d, 1 H, $J_{1,2}$ 1 Hz, H-1), 5.29 (dt, 1 H, H-4), 7.14–7.5 (m, 15 H, 3 Ph). Mass spectrum: *m/z* 531 [0.86%, $(M + Na)^+$], 477 [0.5, $(M - OMe)^+$], 265 [0.65, $(M - Tr)^+$], 243 (1, Tr^+).

Anal. Calcd for $C_{29}H_{32}O_4S_2$: C, 68.47; H, 6.34. Found: C, 68.52; H, 6.44.

*Methyl 2-deoxy-2-(1,3-dithian-2-yl)-5-*O*-trityl-α-*D-xylo-*pentofuranoside* (**11**). — Prepared from **5**, **11** (27.2%) had $[\alpha]_D^{20}$ + 4.2° (*c*, 1, chloroform). ^{1}H-NMR data: δ 2.05 (m, 2 H, CH_2CH_2), 2.83 (m, 4 H, 2 SCH_2), 3.08 (m, 1 H, H-2), 3.45 (s, 3 H, OMe), 3.70 (m, 2 H, OCH_2), 3.91 (m, 1 H, H-3), 4.30 (d, 1 H, $J_{CH,H-2}$ 7 Hz, SCH), 4.61 (d, 1 H, OH), 5.22 (d, 1 H, $J_{1,2}$ 14 Hz, H-1), 5.27 (m, 1 H, H-4), 7.15–7.49 (m, 15 H, 3 Ph). Mass spectrum: *m/z* 531 [0.86%, $(M + Na)^+$], 477 [0.5, $(M - OMe)^+$], 265 [0.65, $(M - Tr)^+$], 243 (1, Tr^+).

Anal. Calcd for $C_{29}H_{32}O_4S_2$: C, 68.47; H, 6.34. Found: C, 68.54; H, 6.38.

Methyl 5-O-tert-butyldiphenylsilyl-3-deoxy-3-(1,3-dithian-2-yl)-α-D-arabino-pentofuranoside (**12**). — Prepared from **6**, **12** (57.8%) had $[\alpha]_D^{20} + 16°$ (*c* 1, chloroform). ^{1}H-NMR data: δ 1.07 (s, 9 H, ^{t}Bu), 2.0 (m, 2 H, CH_2CH_2), 2.81 (m, 4 H, 2 SCH_2), 2.96 (m, 1 H, H-3), 3.45 (s, 3 H, OMe), 3.85 (m, 2 H, OCH_2), 4.26 (d, 1 H, $J_{CH,H-3}$ 7 Hz, SCH), 4.59 (m, 2 H, OH and H-2), 5.12 (d, 1 H, $J_{1,2}$ 1 Hz, H-1), 5.19 (m, 1 H, H-4), 7.28–7.77 (m, 10 H, 2 Ph). Mass spectrum: *m/z* 527 [0.2%, $(M + Na)^+$], 503 [0.15, $(M - H)^+$], 473 [1, $(M - OMe)^+$], 265 [0.6, $(M - {}^tBuPh_2Si)^+$], 234 [0.45, $(M - {}^tBuPh_2Si - OMe)^+$].

Anal. Calcd for $C_{26}H_{36}O_4S_2Si$: C, 61.86; H, 7.19. Found: C, 61.90; H, 7.16.

Methyl 5-O-tert-butyldiphenylsilyl-2-deoxy-2-(1,3-dithian-2-yl)-α-D-xylo-pentofuranoside (**13**). — Prepared from **6**, **13** (27.2%) had $[\alpha]_D^{20} + 12°$ (*c*, 1, chloroform). ^{1}H-NMR data: δ 1.07 [s, 9 H, ^{t}Bu], 2.0 (m, 2 H, CH_2CH_2), 2.81 (m, 4 H, 2 SCH_2), 2.90 (m, 1 H, H-2), 3.45 (s, 3 H, OMe), 3.84 (m, 3 H, H-3 and OCH_2), 4.28 (d, 1 H, $J_{CH,H-2}$ 7 Hz, SCH), 4.60 (d, 1 H, OH), 5.15 (d, 1 H, $J_{1,2}$ 13 Hz, H-1), 5.18 (m, 1 H, H-4), 7.28–7.76 (m, 10 H, 2 Ph). Mass spectrum: *m/z* 527 [0.2%, $(M + Na)^+$], 503 [0.15, $(M - H)^+$], 473 [1, $(M - OMe)^+$], 265 [0.6, $(M - {}^tBuPh_2Si)^+$], 234 [0.45, $(M - {}^tBuPh_2Si - OMe)^+$].

Anal. Calcd for $C_{26}H_{36}O_4S_2Si$: C, 61.86; H, 7.19. Found: C, 62.02; H, 7.21.

Methyl 5-O-benzyl-3-deoxy-3-(1,3-dithian-2-yl)-α-D-arabino-pentofuranoside (**14**). — Prepared from **7**, **14** (74.8%) had $[\alpha]_D^{20} + 14°$ (*c* 1, chloroform). ^{1}H-NMR data: δ 2.05 (m, 2 H, CH_2CH_2), 2.82 (m, 4 H, 2 SCH_2), 2.98 (m, 1 H, H-3), 3.45 (s, 3 H, OMe), 3.70 (m, 2 H, OCH_2), 4.3 (d, 1 H, $J_{CH,H-3}$ 7 Hz, SCH), 4.58 (s, 2 H, $PhCH_2$), 4.62 (s, 1 H, OH), 4.7 (m, 1 H, H-2), 5.12 (d, 1 H, $J_{1,2}$ 1 Hz, H-1), 5.19 (m, 1 H, H-4), 7.33 (s, 5 H, Ph). Mass spectrum: *m/z* 379 [0.8%, $(M + Na)^+$], 356 (0.2, M^+), 355 [0.6, $(M - H)^+$], 325 [0.4, $(M - OMe)^+$], 234 [0.5, $(M - OMe - PhCH_2)^+$].

Anal. Calcd for $C_{17}H_{24}O_4S_2$: C, 57.27; H, 6.79. Found: C, 57.34; H, 6.80.

Methyl 5-O-benzyl-2-deoxy-2-(1,3-dithian-2-yl)-α-D-xylo-pentofuranoside (**15**). — Prepared from **7**, **15** (11.2%) had $[\alpha]_D^{20} + 22°$ (*c* 1, chloroform). ^{1}H-NMR data: δ 2.05 (m, 2 H, CH_2CH_2), 2.82 (m, 4 H, 2 SCH_2), 3.0 (m, 1 H, H-2), 3.45 (s, 3 H, OMe), 3.70 (m, 2 H, OCH_2), 3.90 (m, 1 H, H-3), 4.30 (d, 1 H, $J_{CH,H-3}$ 7 Hz, SCH), 4.58 (s, 2 H, $PhCH_2$), 4.6 (d, 1 H, OH), 5.20 (d, 1 H, $J_{1,2}$ 13 Hz, H-1), 5.25 (m, 1 H, H-4), 7.33 (s, 5 H, Ph). Mass spectrum: *m/z* 379 [0.8%, $(M + Na)^+$], 356 (0.2, M^+), 355 [0.6, $(M - H)^+$], 325 [0.4, $(M - OMe)^+$], 234 [0.5, $(M - OMe - PhCH_2)^+$].

Anal. Calcd for $C_{17}H_{24}O_4S_2$: C, 57.27; H, 6.79. Found: C, 57.30; H, 6.82.

General procedure for reactions with phenylthiomethyl-lithium. — To a stirred solution of 1,4-diazabicyclo[2.2.2]octane (5.6 g, 50 mmol) and thioanisole (5.95 mL, 50 mmol) in tetrahydrofuran (64 mL) under nitrogen at 0° was added butyl-lithium (1.6 M in hexane; 34.4 mL, 55 mmol). The precipitate dissolved upon warming to room temperature to give a pale-yellow solution. After 45 min, the metallation was complete and a solution of **2**, **5**, **6**, or **7** (10 mmol) in dry tetrahydrofuran (20 mL) was added dropwise with vigorous stirring. After 3 h, TLC (CH_2Cl_2–hexane, 8.5 : 1.5) indicated the absence of starting material and the presence of one more

polar product. The mixture was poured into water (250 mL), neutralised with M HCl, and extracted twice with ethyl acetate. The combined extracts were dried ($MgSO_4$) and filtered, and the solvent was evaporated. Column chromatography (CH_2Cl_2–hexane, 8.5:1.5) of the residue gave a mixture of two isomers as an orange gum. Column chromatography (ethyl acetate–hexane, 9:1) gave the C-2 adduct first and then the C-3 adduct, each isolated as a gum.

The following compounds were prepared in this manner.

*Methyl 3-deoxy-3-phenylthiomethyl-α-*D-arabino-*pentofuranoside* (**16**). — Prepared from **2**, **16** (78%) had $[\alpha]_D^{20}$ + 28° (*c* 1, chloroform). ^{1}H-NMR data: δ 2.7 (m, 1 H, H-3), 3.15 (d, 2 H, $J_{CH_2,H-3}$ 7 Hz, SCH_2), 3.44 (s, 3 H, OMe), 3.80 (t, 2 H, $J_{4,5}$ 3 Hz, OCH_2), 4.42 (m, 1 H, H-4), 4.6 (m, 3 H, 2 OH and H-2), 4.91 (s, 1 H, H-1), 7.23 (s, 5 H, Ph). Mass spectrum: *m/z* 269 [0.4%, $(M - H)^+$], 239 [0.6, $(M - OMe)^+$], 222 [0.6, $(M - OH - OMe)^+$], 193 [0.5, $(M - Ph)^+$].

Anal. Calcd for $C_{13}H_{18}O_4S$: C, 57.76; H, 6.71. Found: C, 57.86; H, 6.80.

*Methyl 2-deoxy-2-phenylthiomethyl-α-*D-xylo-*pentofuranoside* (**17**). — Prepared from **2**, **17** (4%) had $[\alpha]_D^{20}$ + 49° (*c* 1, chloroform). ^{1}H-NMR data: δ 3.12 (m, 1 H, H-2), 3.2 (d, 2 H, $J_{CH_2,H-2}$ 6 Hz, SCH_2), 3.43 (s, 3 H, OMe), 3.80 (t, 2 H, $J_{4,5}$ 3 Hz, OCH_2), 4.30 (m, 1 H, H-3), 4.6 (m, 2 H, 2 OH), 5.4 (d, 1 H, $J_{1,2}$ 16 Hz, H-1), 5.60 (m, 1 H, H-4), 7.23 (s, 5 H, Ph). Mass spectrum: *m/z* 269 [0.4%, $(M - H)^+$], 239 [0.6, $(M - OMe)^+$], 222 [0.6, $(M - H - OMe)^+$], 193 [0.5, $(M - Ph)^+$].

Anal. Calcd for $C_{13}H_{18}O_4S$: C, 57.76; H, 6.71. Found: C, 57.86; H, 6.78.

*Methyl 3-deoxy-3-phenylthiomethyl-5-*O*-trityl-α-*D-arabino-*pentofuranoside* (**18**). — Prepared from **5**, **18** (41.4%) had $[\alpha]_D^{20}$ + 26° (*c* 1, chloroform). ^{1}H-NMR data: δ 2.70 (m, 1 H, H-3), 3.15 (d, 2 H, $J_{CH_2,H-3}$ 7 Hz, SCH_2), 3.43 (s, 3 H, OMe), 3.72 (m, 2 H, OCH_2), 4.6 (m, 2 H, OH and H-2), 5.14 (s, 1 H, H-1), 5.52 (m, 1 H, H-4), 7.16–7.68 (m, 20 H, 4 Ph). Mass spectrum: *m/z* 512 (0.3%, M^+), 481 [0.2, $(M - OMe)^+$], 435 [0.6, $(M - Ph)^+$], 269 [0.4, $(M - Tr)^+$], 238 [0.5, $(M - Tr - OMe)^+$].

Anal. Calcd for $C_{32}H_{32}O_4S$: C, 74.97; H, 6.28.. Found: C, 75.12; H, 6.30.

*Methyl 2-deoxy-2-phenylthiomethyl-5-*O*-trityl-α-*D-xylo-*pentofuranoside* (**19**). — Prepared from **5**, **19** (27.6%) had $[\alpha]_D^{20}$ + 15° (*c* 1, chloroform). ^{1}H-NMR data: δ 3.12 (m, 1 H, H-2), 3.15 (d, 2 H, $J_{CH_2,H-3}$ 7 Hz, SCH_2), 3.43 (s, 3 H, OMe), 3.72 (m, 2 H, OCH_2), 4.40 (m, 1 H, H-3), 4.60 (d, 1 H, OH), 5.22 (d, 2 H, $J_{1,2}$ 14 Hz, H-1), 5.32 (m, 1 H, H-4), 7.16–7.68 (m, 20 H, 4 Ph). Mass spectrum: *m/z* 512 (0.3%, M^+), 481 [0.2, $(M - OMe)^+$], 435 [0.6, $(M - Ph)^+$], 269 [0.4, $(M - Tr)^+$], 238 [0.5, $(M - Tr - OMe)^+$].

Anal. Calcd for $C_{32}H_{32}O_4S$: C, 74.97; H, 6.28. Found: C, 75.02; H, 6.30.

*Methyl 5-*O*-tert-butyldiphenylsilyl-3-deoxy-3-phenylthiomethyl-α-*D-arabino-*pentofuranoside* (**20**). — Prepared from **6**, **20** (46%) had $[\alpha]_D^{20}$ + 29° (*c* 1, chloroform). ^{1}H-NMR data: δ 1.07 (s, 9 H, ^{t}Bu), 2.68 (m, 1 H, H-3), 3.36 (d, 2 H, $J_{CH_2,H-3}$ 6 Hz, CH_2S), 3.43 (s, 3 H, OMe), 3.66 (m, 2 H, OCH_2), 4.59 (s, 1 H, OH), 4.88 (q, 1 H, H-2), 5.14 (s, 1 H, H-1), 5.52 (m, 1 H, H-4), 7.16–7.68 (m, 15 H, 3 Ph). Mass spectrum: *m/z* 521 [0.8%, $(M + Na)^+$], 509 [0.4, $(M + 1)^+$], 477 [0.95, $(M - OMe)^+$], 431 [1, $(M - Ph)^+$], 400 [0.6, $(M - Ph - OMe)^+$].

Anal. Calcd for $C_{29}H_{36}O_4SSi$: C, 68.46; H, 7.13. Found: C, 68.56; H, 7.20.

Methyl 5-O-tert-butyldiphenylsilyl-2-deoxy-2-phenylthiomethyl-α-D-xylo-pentofuranoside (**21**). — Prepared from **6**, **21** (28%) had $[\alpha]_D^{20}$ + 18° (*c* 1, chloroform). ^{1}H-NMR data: δ 1.07 (s, 9 H, ^{t}Bu), 3.36 (d, 2 H, $J_{CH_2,H-3}$ 6 Hz, CH_2S), 3.43 (s, 3 H, OMe), 3.60 (m, 1 H, H-2), 3.68 (m, 2 H, OCH_2), 4.58 (m, 2 H, H-3 and OH), 5.18 (d, 1 H, $J_{1,2}$ 12 Hz, H-1), 5.4 (m, 1 H, H-4), 7.16–7.68 (m, 15 H, 3 Ph). Mass spectrum: *m/z* 521 [0.8%, $(M + Na)^+$], 509 [0.4, $(M + 1)^+$], 477 [0.95, $(M - OMe)^+$], 431 [1, $(M - Ph)^+$], 400 [0.6, $(M - Ph - OMe)^+$].

Anal. Calcd for $C_{29}H_{36}O_4SSi$: C, 68.46; H, 7.13. Found: C, 68.55; H, 7.12.

Methyl 5-O-benzyl-3-deoxy-3-phenylthiomethyl-α-D-arabino-pentofuranoside (**22**). — Prepared from **7**, **22** (61.2%) had $[\alpha]_D^{20}$ + 26.5° (*c* 1, chloroform). ^{1}H-NMR data: δ 3.09 (m, 1 H, H-3), 3.14 (d, 2 H, $J_{CH_2,H-3}$ 6 Hz, CH_2S), 3.41 (s, 3 H, OMe), 3.67 (m, 2 H, OCH_2), 4.58 (s, 2 H, PhCH_2), 4.71 (s, 1 H, OH), 4.89 (m, 1 H, H-2), 5.23 (s, 1 H, H-1), 5.53 (m, 1 H, H-4), 7.20–7.50 (m, 10 H, 2 Ph). Mass spectrum: *m/z* 383 [0.85%, $(M + Na)^+$], 359 [0.6, $(M - 1)^+$], 329 [0.7, $(M - OMe)^+$], 283 [0.4, $(M - Ph)^+$], 251 [0.2, $(M - PhS)^+$].

Anal. Calcd for $C_{20}H_{24}O_4S$: C, 66.64; H, 6.71. Found: C, 66.71; H, 6.73.

Methyl 5-O-benzyl-2-deoxy-2-phenylthiomethyl-α-D-xylo-pentofuranoside (**23**). — Prepared from **7**, **23** (23.8%) had $[\alpha]_D^{20}$ + 32° (*c* 1, chloroform). ^{1}H-NMR data: δ 3.12 (m, 1 H, H-2), 3.22 (d, 2 H, $J_{CH_2,H-2}$ 6 Hz, SCH_2), 3.41 (s, 3 H, OMe), 3.67 (m, 3 H, OH and OCH_2), 4.31 (m, 1 H, H-3), 4.58 (s, 2 H, PhCH_2), 5.39 (d, 1 H, $J_{1,2}$ 16 Hz, H-1), 5.6 (m, 1 H, H-4), 7.20–7.50 (m, 10 H, 2 Ph). Mass spectrum: *m/z* 383 [0.85%, $(M + Na)^+$], 359 [0.6, $(M - 1)^+$], 329 [0.7, $(M - OMe)^+$], 283 [0.4, $(M - Ph)^+$], 251 [0.2, $(M - PhS)^+$].

Anal. Calcd for $C_{20}H_{24}O_4S$: C, 66.64; H, 6.71. Found: C, 66.78; H, 6.76.

General procedure for benzoylation. — To a cooled (ice) solution of a 3-substituted arabinofuranoside (10 mmol) and sodium hydride (50% suspension in oil, 0.58 g, 12 mmol) in anhydrous *N*,*N*-dimethylformamide (20 mL) was added benzoyl bromide (1.42 mL, 24 mmol) dropwise, under N_2. The mixture was stirred at room temperature under N_2 for 4 h. When TLC (ethyl acetate–hexane, 9:1) indicated reaction to be complete, the mixture was poured into ice–water, the aqueous layer was extracted with ethyl acetate (3 × 50 mL), the combined extracts were washed with M HCl, aq satd $NaHCO_3$, and aq satd NaCl, and dried ($MgSO_4$), and the solvent was evaporated. Column chromatography (ethyl acetate–hexane, 9:1) of the residue then gave the 2-benzoate.

Treatment of **8** (2.6 g, 10 mmol) with benzoyl bromide (2.84 mL, 24 mmol) in the presence of sodium hydride (50% suspension in oil; 1.16 g, 24 mmol) as described above gave methyl 2-*O*-benzoyl-3-deoxy-3-(1,3-dithian-2-yl)-α-D-*arabino*-pentopyranoside (2.15 g, 58%) and the expected arabinofuranoside 2,5-dibenzoate **24** (0.5 g, 10.6%).

The following compounds were prepared in this manner.

Methyl 2,5-di-O-benzoyl-2-deoxy-(1,3-dithian-2-yl)-α-D-arabino-pentofuranoside (**24**). — Prepared from **8**, **24** had $[\alpha]_D^{20}$ + 48° (*c* 1, chloroform). ^{1}H-NMR data: δ

2.05 (m, 2 H, CH_2CH_2), 2.82 (m, 4 H, 2 SCH_2), 3.28 (m, 1 H, H-3), 3.45 (s, 3 H, OMe), 3.64 (m, 2 H, OCH_2), 3.8 (m, 1 H, H-2), 4.3 (d, 1 H, $J_{CH,H-3}$ 7 Hz, SCH), 5.12 (s, 1 H, H-1), 5.28 (m, 1 H, H-4), 7.26–7.53 (m, 8 H, aromatic), 8.02–8.09 (m, 2 H, aromatic). Mass spectrum: *m/z* 474 (0.4%, M^+), 443 [0.5, $(M - OMe)^+$], 380 [0.2, $(M - PhCO)^+$], 275 [0.3, $(M - 2PhCO)^+$].

Anal. Calcd for $C_{24}H_{26}O_6S_2$: C, 60.74; H, 5.52. Found: C, 60.65; H, 5.48.

*Methyl 2-O-benzoyl-3-deoxy-3-(1,3-dithian-2-yl)-5-O-trityl-α-*D-arabino-*pentofuranoside* (**25**). — Prepared from **10** (5.08 g, 10 mmol), **25** (2.57 g, 42%) had $[\alpha]_D^{20} + 24°$ (*c* 1, chloroform). The ^{1}H-NMR spectrum was similar to that of **10**, except for the signals at δ 7.20–8.20 (m 20 H, 4 Ph) and 3.82 (H-2). Mass spectrum: *m/z* 612 (0.35%, M^+), 581 [0.65, $(M - OMe)^+$], 369 [0.4, $(M - Tr)^+$].

Anal. Calcd for $C_{36}H_{36}O_5S_2$: C, 70.56; H, 5.92. Found: C, 70.62; H, 5.98.

*Methyl 2-O-benzoyl-5-O-*tert*-butyldiphenylsilyl-3-deoxy-3-(1,3-dithian-2-yl)-α-*D-arabino-*pentofuranoside* (**26**). — Prepared from **12** (5.04 g, 10 mmol), **26** (2.55 g, 42%) had $[\alpha]_D^{20} + 28°$ (*c* 1, chloroform). The ^{1}H-NMR spectrum was similar to that of **12**, except for the signals at δ 7.2–8.2 (m, 15 H, 3 Ph) and 3.83 (H-2). Mass spectrum: *m/z* 608 (0.25%, M^+), 577 [0.5, $(M - OMe)^+$], 338 [0.3, $(M - {}^tBuPh_2Si)^+$], 261 [0.4, $(M - {}^tBuPh_2Si - Ph)^+$].

Anal. Calcd for: $C_{33}H_{40}O_5S_2Si$: C, 65.09; H, 6.62. Found: C, 65.2; H, 6.70.

*Methyl 2-O-benzoyl-5-O-benzyl-3-deoxy-3-(1,3-dithian-2-yl)-α-*D-arabino-*pentofuranoside* (**27**). — Prepared from **14** (3.56 g, 10 mmol), **27** (3 g, 66%) had $[\alpha]_D^{20} + 32°$ (*c* 1, chloroform). The ^{1}H-NMR spectrum was similar to that of **14**, except for the signals at δ 7.20–8.10 (m, 10 H, 2 Ph) and 3.85 (H-2). Mass spectrum: *m/z* 461 [0.55%, $(M + H)^+$], 460 (0.3, M^+), 429 [0.6, $(M - OMe)^+$], 383 [0.4, $(M - Ph)^+$], 369 [0.3, $(M - PhCH_2)^+$].

Anal. Calcd for $C_{24}H_{28}O_5S_2$: C, 62.58; H, 6.13. Found: C, 62.64; H, 6.10.

Treatment of **16** (2.7 g, 10 mmol) with benzoyl bromide (2.84 mL, 24 mmol) in the presence of sodium hydride (50% in oil; 1.16 g, 24 mmol) by the general procedure gave mainly methyl 2-*O*-benzoyl-3-deoxy-3-phenylthiomethyl-α-D-*arabino*-pentopyranoside (2 g, 54%) and the arabinofuranoside 2,5-dibenzoate **28** (0.4 g, 8.3%).

*Methyl 2,5-di-O-benzoyl-3-deoxy-3-phenylthiomethyl-α-*D-arabino-*pentofuranoside* (**28**). — Prepared from **16**, **28** had $[\alpha]_D^{20} + 52°$ (*c* 1, chloroform). ^{1}H-NMR data: δ 2.71 (m, 1 H, H-3), 3.15 (d, 2 H, $J_{CH_2,H-3}$ 7 Hz, SCH_2), 3.44 (s, 3 H, OMe), 3.81 (t, 2 H, $J_{4,5}$ 3 Hz, OCH_2), 3.94 (dd, 1 H, H-2), 5.18 (s, 1 H, H-1), 5.29 (m, 1 H, H-4), 7.20–8.10 (m, 15 H, 3 Ph). Mass spectrum: *m/z* 408 (0.4%, M^+), 377 [0.6, $(M - OMe)^+$], 331 [0.5, $(M - Ph)^+$], 285 [0.55, $(M - PhSCH_2)^+$].

Anal. Calcd for $C_{27}H_{26}O_6S$: C, 67.76; H, 5.47. Found: C, 67.86; H, 5.50.

*Methyl 2-O-benzoyl-3-deoxy-3-phenylthiomethyl-5-O-trityl-α-*D-arabino-*pentofuranoside* (**29**). — Prepared from **18** (5.12 g, 10 mmol), **29** (2.5 g, 40.5%) had $[\alpha]_D^{20} + 27°$ (*c* 1, chloroform). The ^{1}H-NMR spectrum was similar to that for **18** except for the signals at δ 7.20–8.20 (m, 25 H, 5 Ph) and 3.88 (H-2). Mass spectrum: *m/z* 616 (0.25%, M^+), 585 [0.5, $(M - OMe)^+$], 511 [0.4, $(M - PhCO)^+$], 493 [0.3, $(M - PhSCH_2)^+$], 373 [0.6, $(M - Tr)^+$].

Anal. Calcd for $C_{39}H_{36}O_5S$: C, 75.95; H, 5.88. Found: C, 76.10; H, 5.86.

*Methyl 2-O-benzoyl-5-O-*tert*-butyldiphenylsilyl-3-deoxy-3-phenylthiomethyl-α-*D*-arabino-pentofuranoside* (**30**). — Prepared from **20** (5.08 g, 10 mmol), **30** (2.94 g, 48%) had $[\alpha]_D^{20} + 32°$ (*c* 1, chloroform). The ^{1}H-NMR spectrum was similar to that for **20** except for the signals at δ 7.20–8.20 (m, 20 H, 4 Ph) and 3.90 (H-2). Mass spectrum: *m/z* 612 (0.4%, M^+), 581 [0.7, $(M - OMe)^+$], 535 [0.5, $(M - Ph)^+$], 507 [0.4, $(M - PhCO)^+$], 489 [0.3, $(M - PhSCH_2)^+$].

Anal. Calcd for $C_{36}H_{40}O_5SSi$: C, 70.55; H, 6.58. Found: C, 70.70; H, 6.62.

*Methyl 2-O-benzoyl-5-O-benzyl-3-deoxy-3-phenylthiomethyl-α-*D*-arabino-pentofuranoside* (**31**). — Prepared from **22** (3.6 g, 10 mmol), **31** (2.69 g, 58%) had $[\alpha]_D^{20} + 36°$ (*c* 1, chloroform). The ^{1}H-NMR spectrum was similar to that for **22** except for the signals at δ 7.20–8.20 (m, 15 H, 3 Ph) and 3.86 (H-2). Mass spectrum: *m/z* 464 (0.75%, M^+), 433 [0.8, $(M - OMe)^+$], 359 [0.4, $(M - PhCO)^+$], 355 [0.4, $(M - PhS)^+$].

Anal. Calcd for $C_{27}H_{28}O_5S$: C, 69.80; H, 6.07. Found: C, 69.76; H, 6.10.

General procedure for hydrolysis of 3-(1,3-dithian-2-yl)-arabinofuranosides. — A solution of the substrate (1 mmol) in tetrahydrofuran (2 mL) was added dropwise during 10 min to a vigorously stirred mixture of red mercuric oxide (0.47 g, 2.2 mmol) and boron trifluoride etherate (0.34 mL, 2.8 mmol) in aq 15% tetrahydrofuran (5 mL) under N_2. Stirring was continued for 5 h at room temperature, CH_2Cl_2 (15 mL) was added, the mixture was filtered, washed to pH 10 with aq satd Na_2CO_3 and to neutrality with aq satd NaCl, and dried ($MgSO_4$), and the solvent was evaporated under reduced pressure to leave the crude aldehyde. To a suspension of 2,4-dinitrophenylhydrazine (0.25 g) in MeOH (5 mL) was added concd H_2SO_4 (0.4–0.5 mL). The warm solution was filtered, a solution of the formyl compound (0.1–0.2 g) in a small volume of chloroform was added, and, after 10 min, the solid was collected, washed with a little aq MeOH, and recrystallised from EtOH.

The following compounds were prepared in this manner.

*Methyl 5-O-benzyl-3-deoxy-3-C-formyl-α-*D*-arabino-pentofuranoside* (**1a**). — Prepared from **14**, **1a** (0.21 g, 80.3%) had $[\alpha]_D^{20} + 76°$ (*c* 1, chloroform). ^{1}H-NMR data: δ 2.99 (m, 1 H, H-3), 3.43 (s, 3 H, OMe), 3.64 (m, 2 H, OCH_2), 4.58 (s, 2 H, PhCH_2), 4.66 (m, 2 H, OH and H-2), 4.95 (s, 1 H, H-1), 5.13 (m, 1 H, H-4), 7.33 (s, 5 H, Ph), 10.02 (s, 1 H, CHO). Mass spectrum: *m/z* 289 [0.8%, $(M + Na)^+$], 265 [0.6, $(M - H)^+$], 235 [0.5, $(M - OMe)^+$], 175 [0.2, $(M - PhCH_2)^+$].

The 2,4-dinitrophenylhydrazone of **1a** had mp 122°.

Anal. Calcd for $C_{20}H_{21}N_4O_8$: C, 53.84; H, 4.93. Found: C, 54.12; H, 4.97.

*Methyl 2,5-di-O-benzoyl-3-deoxy-3-C-formyl-α-*D*-arabino-pentofuranoside* (**1b**). — Prepared from **24**, **1b** (0.31 g, 80.8%) had $[\alpha]_D^{20} + 87°$ (*c* 1, chloroform). ^{1}H-NMR data: δ 3.10 (m, 1 H, H-3), 3.43 (s, 3 H, OMe), 3.64 (m, 2 H, OCH_2), 3.76 (m, 1 H, H-2), 4.95 (s, 1 H, H-1), 5.13 (m, 1 H, H-4), 7.26–8.12 (m, 10 H, 2 Ph), 10.02 (s, 1 H, CHO). Mass spectrum: *m/z* 384 (0.3%, M^+), 353 [0.5, $(M - OMe)^+$], 184 [0.8, $(M - 2PhCO)^+$].

The 2,4-dinitrophenylhydrazone of **1b** had mp 129°.

Anal. Calcd for $C_{27}H_{24}N_4O_{10}$: C, 57.48; H, 4.25. Found: C, 57.33; H, 4.22.

Methyl 2-O-benzoyl-5-O-tert-butyldiphenylsilyl-3-deoxy-3-C-formyl-α-D-arabino-pentofuranoside (**1c**). — Prepared from **26** (0.608 g, 1 mmol), **1c** (0.052 g, 10%) had $[\alpha]_D^{20}$ + 67° (*c* 1, chloroform). ^{1}H-NMR data: δ 1.07 (s, 3 H, ^{t}Bu), 2.99 (m, 1 H, H-3), 3.44 (s, 3 H, OMe), 3.83 (m, 1 H, H-2), 3.85 (m, 3 H, OCH_2 and H-2), 5.02 (s, 1 H, H-1), 5.10 (m, 1 H, H-4), 7.20–8.20 (m, 15 H, 3 Ph), 9.98 (s, 1 H, CHO). Mass spectrum: *m/z* 518 (0.4%, M^+), 487 [0.6, $(M - OMe)^+$], 413 [0.3, $(M - PhCO)^+$].

The 2,4-dinitrophenylhydrazone of **1c** had mp 128°.

Anal. Calcd for $C_{36}H_{38}N_4O_9Si$: C, 61.91; H, 5.44. Found: C, 62.08; H, 5.49.

Methyl 2-O-benzoyl-5-Obenzyl-3-deoxy-3-C-formyl-α-D-arabino-pentofuranoside (**1d**). — Prepared from **27** (0.46 g, 1 mmol), **1d** (0.3 g, 81%) had $[\alpha]_D^{20}$ + 72° (*c* 1, chloroform). ^{1}H-NMR data: δ 2.99 (m, 1 H, H-3), 3.44 (s, 3 H, OMe), 3.64 (m, 2 H, OCH_2), 3.77 (m, 1 H, H-2), 4.58 (s, 2 H, $PhCH_2$), 5.01 (s, 1 H, H-1), 5.12 (m, 1 H, H-4), 7.20–8.20 (m, 10 H, 2 Ph), 10.02 (s, 1 H, CHO). Mass spectrum: *m/z* 370 (0.3%, M^+), 339 [0.8, $(M - OMe)^+$], 263 [0.6, $(M - PhCH_2O)^+$].

The 2,4-dinitrophenylhydrazone of **1d** had mp 122°.

Anal. Calcd for $C_{27}H_{26}N_4O_9$: C, 58.94; H, 4.72. Found: C, 58.98; H, 4.78.

Deprotection of **28** *and* **31**. — To a stirred solution of **28** or **31** (1 mmol) in MeOH (25 mL) was added a solution of sodium periodate (0.32 g, 1.5 mmol) in water (15 mL). After 2 h at room temperature, the reaction was complete (TLC; ethyl acetate–hexane, 9:1) and the solvent was evaporated in vacuo. The residue was washed twice with water and then extracted with acetone, the extract was filtered, and the solvent was evaporated under reduced pressure to leave the sulphoxide as a gum, which was used in the next step without purification.

To a solution of the crude sulphoxide (1 mmol) in acetonitrile (6 mL) and 2,4,6-collidine (0.27 mL, 2 mmol) was added a solution of trifluoroacetic anhydride (0.28 mL, 2 mmol) in acetonitrile (2 mL) at 0° under N_2. The mixture was stirred at 0° for 10 min, aq $NaHCO_3$ (10 mL, 0.5 g, 6 mmol) was added, and stirring was continued at room temperature for 2 h. Ethyl acetate (20 mL) was added, the solution was partitioned between ethyl acetate and water, the ethyl acetate phase was washed with dilute HCl and aq satd $NaHCO_3$, then dried ($MgSO_4$), and the solvent was evaporated under reduced pressure to give the crude aldehyde Column chromatography (ethyl acetate–hexane, 9:1) then gave **1b** (0.26 g, 69%) or **1d** (0.25 g, 69%), identical with the products described above.

REFERENCES

1 M.J. Bamford, P.L. Coe, and R.T. Walker, *J. Med. Chem.*, 33 (1990) 2488–2494; 2494–2508.

2 N.R. Williams, *Adv. Carbohydr. Chem. Biochem.*, 25 (1970) 109–179; R.D. Guthrie, in W. Pigman and D. Horton (Eds.), *The Carbohydrates*, Vol. IA, Academic Press, New York, 1972, pp. 423–478; R.J. Ferrier and P.M. Collins, *Monosaccharide Chemistry*, Penguin, 1972, p. 116; F.M. Unger, R. Christian, and P. Waldstätten, *Carbohydr. Res.*, 67 (1978) 257–262; C.D. Anderson, L. Goodman, and B.R. Baker, *J. Am. Chem. Soc.*, 80 (1958) 5247; B.R. Baker and R.E. Schaub, *ibid.*, 77 (1955)

5900; J.A. Wright and N.F. Taylor, *Carbohydr. Res.*, 3 (1967) 333–339; J.M. Anderson and E. Percival, *J. Chem. Soc.*, (1956) 819–823; J. Davoll, B. Lythgoe, and S. Trippett, *ibid.*, (1951) 2230; A. Banaszek and A. Zamojski, *Carbohydr. Res.*, 51 (1976) 276–279.

3 A.M. Sepulchre, G. Lukacs, G. Vass, and S.D. Gero, *C.R. Acad. Sci., Ser. C*, 273 (1971) 1180–1182; H. Paulsen, V. Sinnwell, and P. Stadler, *Angew. Chem.*, 84 (1972) 112–113; *Chem. Ber.*, 105 (1972) 1978–1988.

4 T. Kozluk and A. Zamojski, *Collect. Czech. Chem. Commun.*, 48 (1983) 1659–1668; *Tetrahedron*, 39 (1983) 805–810; K. Tatsuta, S. Miyashita, K. Akimoto, and M. Kinoshita, *Bull. Chem. Soc. Jpn.*, 55 (1982) 3254.

5 B.R. Baker, R.E. Schaub, and J.H. Williams, *J. Am. Chem. Soc.*, 77 (1955) 7–12.

6 M.G. Martin, B. Ganem and J.R. Rasmussen, *Carbohydr. Res.*, 123 (1983) 332–334.

7 E.J. Corey and D. Seebach, *Angew. Chem. Int. Ed. Engl.*, 4 (1965) 1075–1078; *Angew. Chem*, 77 (1965) 1134–1135; *J. Org. Chem.*, 40 (1975) 231–237; D. Seebach, *Synthesis*, (1969) 17–36; *Angew. Chem.*, 8 (1969) 690; *Angew. Chem. Int. Ed. Engl.*, 8 (1969) 639–649.

8 B. Grobel and D. Seebach, *Synthesis*, (1977) 357–402; D. Seebach and A.L. Beck, *Org. Synth.*, 51 (1971) 76–80.

9 E. Vedejs and P.L. Fuchs, *J. Org. Chem.*, 36 (1971) 366–367; A.M. Sepulchre, G. Lukacs, G. Vass, and S.D. Gero, *Angew. Chem.*, 84 (1971) 11; J.D. Wander and D. Horton, *Adv. Carbohydr. Chem. Biochem.*, 32 (1976) 37–43; L. Castellanos, A. Gateau-Olesker, F. Panne-Jacolot, J. Cleophax, and S.D. Gero, *Tetrahedron*, 37 (1981) 1691–1696.

10 H. Paulsen, M. Stubbe, and F.R. Heiker, *Liebigs Ann. Chem.*, 6 (1980) 825–837.

11 E.J. Corey and D. Seebach, *J. Org. Chem.*, 31 (1966) 4097–4099; A.W. Herriot, *Synthesis*, (1975) 447–450.

12 W.A. Butte, *J. Org. Chem.*, 29 (1964) 2928; C.G. Screttas and J.F. Eastham, *J. Am. Chem. Soc.*, 87 (1965) 3276.

13 J.K. Williams and E.O. Brien, *U.S.N.T.I.S., AD. REP.*, AD. A020325 (1975); *Chem. Abstr.*, 85 (1976) 5971g.

14 M. Chmielewski, A. Konowal, and A. Zamojski, *Carbohydr. Res.*, 70 (1979) 275–282; M. Chmielewski, O. Achmatowicz, Jr., and A. Zamojski, *Bull. Acad. Pol. Sci., Ser. Sci. Chim.*, 32 (1984) 19–28.

15 M.J. Robins, Y. Fouron, and R. Mengels, *J. Org. Chem.*, 39 (1974) 1564–1570; K. Miyai, R.K. Robins, and R.L. Tolman, *J. Med. Chem.*, 15 (1972) 1092; M. Ashwell, A.S. Jones, and R.T. Walker, *Nucleic Acids Res.*, 15 (1987) 2157–2159.

16 P. Shelly and L. Weiler, *Can. J. Chem.*, 66 (1988) 1359–1365.

17 M. Miljkovic, D. Dropkin, P. Hagel, and M. Habash-Marino, *Carbohydr. Res.*, 128 (1984) 11–20; D. Miljkovic, M. Popsavin, V. Popsavin, N. Vukojevic, J. Harangi, and M. Mak, *ibid.*, 194 (1989) 300–304; E.J. Corey and B.W. Erickson, *J. Org. Chem.*, 36 (1971) 3553–3560.

18 A.M. Sepulchre, G. Lukacs, G. Vass, and S.D. Gero, *Bull. Soc. Chim. Fr.*, 10 (1972) 4000–4007; H. Paulsen, V. Sinnwell, and P. Sadler, *Angew. Chem. Int. Ed. Engl.*, 11 (1972) 149–150.

19 H. Sugihara, R. Tanikaga, and A. Kaji, *Synthesis*, (1978) 881–883; R. Tanikaga, Y. Hiraki, N. Ono, and A. Kaji, *J. Chem. Soc., Chem. Commun.*, (1980) 41–42; B. Lindberg and H. Lundström, *Acta Chem. Scand.*, 22 (1968) 1861–1865; W.E. Parham and L.D. Edwards, *J. Org. Chem.*, 33 (1968) 4150–4154.