Anthracyclinones, Part 4.[1] The Use of DBN or DBU in a Novel Extension of the Marschalk Reaction leading to Hydroxyglycitylanthraquinones

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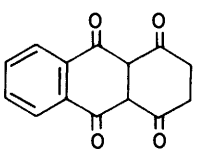
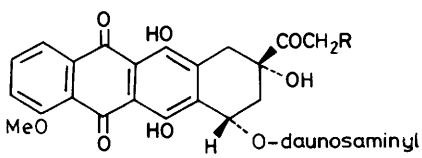
Leuco-quinizarin (**1**) with propanal, 3-*O*-(*p*-chlorobenzyl)- (or 3-*O*-acetyl)-1,2-*O*-isopropylidene-α-D-*xylo*-pentodialdo-1,4-furanose (**6a**) or (**6c**), or 3-*O*-acetyl-3-*C*-ethynyl-1,2-*O*-isopropylidene-α-D-*ribo*-pentodialdo-1,4-furanose (**6b**) in dimethylformamide solution at 0 °C, under nitrogen with DBN or DBU followed by aerial oxidation, gave a good yield of the crystalline 1-(hydroxypropyl)quinizarin (**3**), (5*S*)-3-*O*-(*p*-chlorobenzyl) (or 5-*O*-acetyl)-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-xylofuranose (**7a**) and (**7e**) and 3-*O*-acetyl-3-*C*-ethynyl-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-ribofuranose (**7c**) respectively. Oxidation of (**7a**) with pyridinium chlorochromate produced the oxo derivative (**8**) and acid hydrolysis gave the quinizarinylpyranose (**9**) which with periodate followed by alkali afforded the crystalline (4*S*)-2-*O*-(*p*-chlorobenzyl)-4-(quinizarin-2-yl)-D-*threo*-pentofuranose (**11**) and the dehydration product (**12**). Reduction of (**11**) with alkaline sodium dithionite produced the crystalline (10*S*)-8-*O*-(*p*-chlorobenzyl)anthracyclinone (**14a**) and the corresponding deoxy derivative (**14b**). Structures of the compounds were confirmed by u.v., mass, i.r., c.d., and ^{1}H n.m.r. spectroscopy.

In recent publications[2-5] we have described a novel modification of the Marschalk[6,7] reaction in which an aldehydo carbohydrate (used as an aldehyde and chiral template source) is condensed with *leuco*-quinizarin (**1**) in a mixture of tetrahydrofuran (THF), methanol, and aqueous sodium hydroxide to provide a stereospecific synthesis of hydroxyglycitylanthraquinones which are readily converted into anthracyclinones. The latter constitute the aglycone units of the anthracycline group of antibiotics[8-11] which include the antitumour drugs adriamycin (**2a**) and daunomycin (**2b**). The use of aqueous sodium hydroxide solutions in these reactions may in certain cases pose specific problems. It may, for example, be difficult to carry out reactions on a large scale since substantial volumes of solvents may be required to ensure solubility of all reactants in the aqueous–non-aqueous mixture. In addition, aqueous sodium hydroxide destroys some carbohydrate (especially acyl) derivatives we would like to use. For these and other reasons we have been interested in exploring the possibility of carrying out the reaction in a non-aqueous solvent. We have now shown that this is possible.



(**1**)



(**2**)

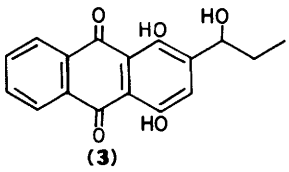
a; R = H, adriamycin
b; R = OH, daunomycin
daunosamine = 3-amino-2,3,6-trideoxy-L-*lyxo*-hexose

In a preliminary experiment it was soon established that reaction of *leuco*-quinizarin (**1**) with propanal and 1,5-diazabicyclo[4.3.0]non-5-ene (DBN) or 1,5-diazabicyclo[5.4.0]-undec-5-ene (DBU) in dimethylformamide (DMF) followed by aeration and acidification gave a good yield of the hydroxypropylquinizarin (**3**). Some appropriate aldehydo carbohydrates were then examined under similar conditions.

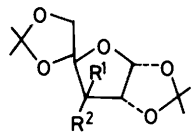
1,2:5,6-Di-*O*-isopropylidene-α-D-glucofuranose (**4a**), sodium hydride, and *p*-chlorobenzyl chloride in dimethyl sulphoxide (DMSO) at 50 °C for 1.5 h gave the *O*-(*p*-chlorobenzyl) derivative (**4b**) which with aqueous acetic acid followed by periodate oxidation of the ensuing diol (**5a**) gave the aldehyde (**6a**), the structure of which was confirmed by mass spectrometry (*m/z* 313, 315) and i.r. spectroscopy [$\nu_{max.}$ 1 740 cm^{-1} (CHO) and 1 380 cm^{-1} (CMe_2)]. A solution of the aldehyde and *leuco*-quinizarin (**1**) in DMF at 0 °C under nitrogen with DBN or DBU was monitored by t.l.c. Reaction appeared to be complete within 5 min to produce, after aerial oxidation and acid treatment, a major product (R_F 0.5), unchanged *leuco*-quinizarin (**1**) (R_F 0.81), and a minor compound, which were separated by chromatography on silica gel to give the hydroxyglycitylquinizarin (**7a**) which readily crystallised from ethanol as orange-red needles (40% yield), m.p. 148 °C.

The structure assigned to compound (**7a**) was confirmed by acetylation to produce a tri-*O*-acetate (**7b**), the elemental analysis, i.r. [*e.g.*, $\nu_{max.}$ 1 380 cm^{-1} (CMe_2)], mass (*e.g.*, *m/z* 552, 554), and u.v. spectra of which were typical of monosubsituted quinizarins; its ^{1}H n.m.r. spectrum showed *e.g.*, absence of a signal for 2'-H; signals at δ 7.64 (3'-H) and 3.85 (1 H, d, $J_{5,5\text{-OH}}$, 2.8 Hz 5-OH, exch. with D_2O) and full assignment of all other protons. The same compound (m.p. and mixed m.p. 148 °C; identical i.r. spectra) was also obtained in similar yield when the reaction of aldehyde (**6a**) and *leuco*-quinizarin (**1**) was carried out in aqueous sodium hydroxide, methanol, and THF, but under these conditions completion of the reaction required 2.5 h at room temperature and the solution volume required was about ten times that used in the new preparation.

The spectroscopic data and homogeneity of the material on



(3)



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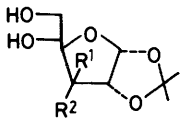
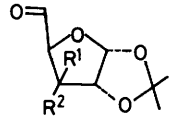


(5)

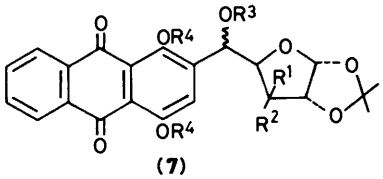
a; R^1 = OH, R^2 = H
b; R^1 = $OCH_2C_6H_4Cl$ (*p*), R^2 = H
c; R^1 = C≡CH, R^2 = OH
d; R^1 = C≡CH, R^2 = OAc
e; R^1 = OAc, R^2 = H

a; R^1 = $OCH_2C_6H_4Cl$ (*p*), R^2 = H
b; R^1 = C≡CH, R^2 = OAc
c; R^1 = OAc, R^2 = H



(6)

a; R^1 = $OCH_2C_6H_4Cl$ (*p*), R^2 = H
b; R^1 = C≡CH, R^2 = OAc
c; R^1 = OAc, R^2 = H

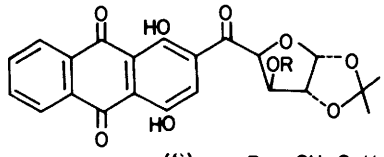


(7)

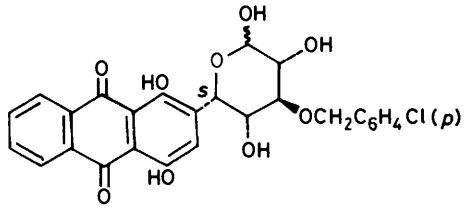
a; R^1 = $OCH_2C_6H_4Cl$ (*p*), R^2 = R^3 = R^4 = H (5*S*)
b; R^1 = $OCH_2C_6H_4Cl$ (*p*), R^2 = H, R^3 = R^4 = Ac (5*S*)
c; R^1 = C≡CH, R = OAc, R^3 = R^4 = H
d; R^1 = OAc, R^2 = R^3 = R^4 = H
e; R^1 = OH, R^2 = R^4 = H, R^3 = Ac (5*R*)

t.l.c. in several solvent systems suggested that it is a single diastereoisomer and comparison of its c.d. spectrum (Figure) with that of compounds of known chirality established it to have the *S*-configuration at the new asymmetric centre produced at C-5.

Oxidation of (**7a**) with pyridinium chlorochromate gave an excellent yield of the 5-oxo derivative (**8**) [*m/z* 267 (QCO^+, 100%) (Q = quinizarin-2-yl)] and hydrolysis with hot aqueous acetic acid provided the pyranose derivative (**9**), the structure of which was confirmed by elemental analysis, and mass [*e.g.*, 512, 514 (M^+)] and ^{1}H n.m.r. [*e.g.*, coupling of 5-H with only 4-H (*J* 10 Hz) with no evidence for 5-H, 5-OH coupling and assignment of all protons] spectra. Reaction of the compound with sodium metaperiodate gave a mixture of products [probably the *O*-formyl derivative (**10**)] which was treated with 1M-sodium hydroxide to produce the 4*S* derivative (**11**) and a second product. The structure assigned to compound (**11**) was confirmed by elemental analysis, and mass [*e.g.*, *m/z* 464 ($M^+ - H_2O$), 269] and ^{1}H n.m.r. (assignment of all protons) spectra. The second compound had an elemental composition



(8) R = $CH_2C_6H_4Cl$ (*p*)



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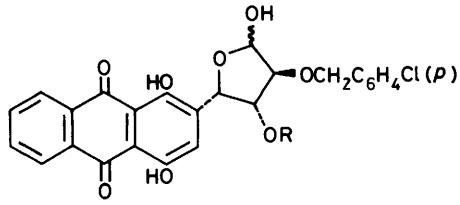
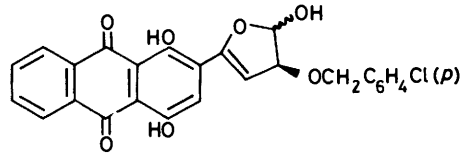


(10) R = CHO
(11) R = H



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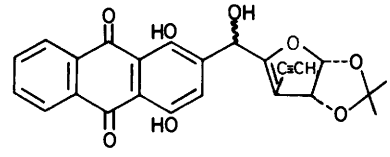

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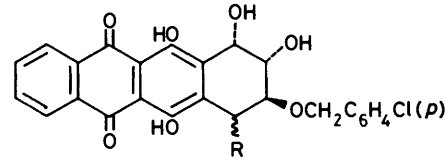

(14)

a; R = OH
b; R = H

corresponding to that of (**11**) minus water [464, 466 (M^+); *m/z* 269 (Q − CHOH)], suggesting the dihydrofuran structure (**12**).

Treatment of the 4*S* derivative (**11**) with sodium dithionite and sodium hydroxide in methanol and THF for 45 min gave, after oxidation, acidification and chromatography, the crystalline anthracyclinone (**14a**) and the 7-deoxy derivative (**14b**). The structure of (**14a**) was confirmed by elemental analysis, and mass [*e.g.*, *m/z* 466, 468 (M^+), 448, 450 ($M^+ - H_2O$), and 125, 127 ($ClC_7H_6^+$)], u.v. (characteristic of a 2,3-disubstituted quinizarin), and ^{1}H n.m.r. (*e.g.*, absence of

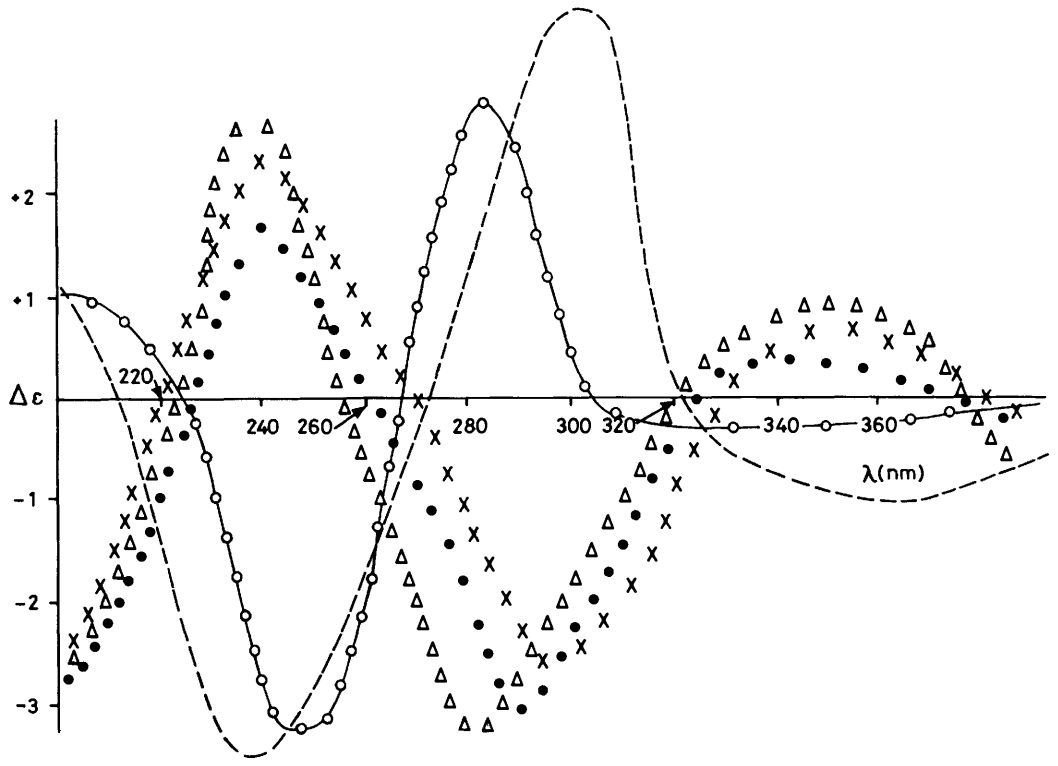

Figure. C.d. spectra of some hydroxyglycitylquinizarins. ——— (5*R*)-3-*C*-Ethynyl-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-ribofuranose.[1] ••• (5*S*)-3-*C*-Ethynyl-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-ribofuranose.[1] × × × (5*S*)-3-*O*-Benzyl-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-xylofuranose.[4,5] △ △ △ (5*S*)-3-*O*-(*p*-Chlorobenzyl)-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-xylofuranose (**7a**) (this work). o o o (5*R*)-5-*O*-Acetyl-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-xylofuranose (**7e**) (this work)

signal for 3′-H, and assignment of all protons) spectra. Similarly, the structure of the deoxy derivative (**14b**) was confirmed by elemental analysis, and mass [*e.g.*, *m/z* 466, 468 (M^+), 448, 450 ($M - H_2O$), and 125, 127 ($C_7H_6^+Cl$, 100 and 30%)], and ^{1}H n.m.r. (*e.g.*, absence of signal for 3′-H, and assignment of all the protons) spectra.

It was of special importance to establish whether the new method of condensation would be applicable to a base-labile OH-protective group such as acetyl. Accordingly, 3-*C*-ethynyl-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose[1] (**4c**) was acetylated with acetic anhydride in pyridine to produce the crystalline *O*-acetate (**4d**) which, with aqueous acetic acid at room temperature during 24 h, gave the mono-*O*-isopropylidene diol (**5b**) with full retention of the *O*-acetyl group. The latter compound with sodium metaperiodate gave the aldehyde (**6b**) [($\nu_{max.}$ 1 735 cm^{-1} (CHO)] which was condensed immediately with *leuco*-quinizarin (**1**) and DBN in DMF at 0 °C under nitrogen for 25 min. Aeration of the mixture followed by acidification produced a solid which, in addition to unchanged quinizarin, contained two products. These were readily separated by chromatography on silica gel. The major product, m.p. 182 °C, readily crystallised, and its analytical and spectroscopic data were in agreement with the expected hydroxyglycityl structure (**7c**) for the compound. In particular, mass [*e.g.*, *m/z* 494 (M^+)], i.r. [*e.g.*, $\nu_{max.}$ 1 380 (CMe_2) and 3 290 cm^{-1} (C≡CH)], and u.v. spectra were typical of monosubstituted quinizarins. Also, the ^{1}H n.m.r. spectrum [*e.g.*, absence of a signal for 2′-H; signals at δ 7.4—7.5 (3′-H) and 1.3, 1.5 (6 H, CMe_2)] confirmed the structure. The splitting of several signals, *e.g.* δ 1.9, 2.1 (3 H, s, CH_3CO), suggested that the compound was a mixture of the 5*R*- and 5*S*-isomer in the ratio 1:2.5.

The minor product formed in the reaction may be assigned the dihydrofuran structure (**13**) which was confirmed by elemental analysis and mass [*e.g.*, *m/z* 434, 436 (M^+) and 269 ($Q-CHOH^+$)] and ^{1}H n.m.r. spectra.

Acetylation of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**4a**) furnished the acetate (**4e**)[12] which was readily converted by mild acid hydrolysis into the diol (**5c**) and treatment of this with sodium metaperiodate afforded the aldehyde[13] (**6c**) which, with *leuco*-quinizarin (**1**) and DBN, gave, after aeration and acidification, a good yield of a crystalline compound which had analytical and spectral data in general agreement with that expected of the hydroxyglycityl structure (**7d**).

However, in contrast to (**7c**) we prefer to assign the 5-*O*-acetyl structure (**7e**) to this compound. Evidence in support of this comes largely from ^{1}H n.m.r. spectral data. In particular, in all previously prepared examples of similar hydroxyglycityl-quinizarins the 5-OH group occurs as a doublet (δ 3—4, $J_{5\text{-OH},5\text{-H}}$ 3 Hz). In the new compound, however, the aliphatic OH group, which is readily differentiated from the phenolic OH groups, gives a signal (δ 5.67) which is a singlet and readily assigned to C-3 in (**7e**) by analogy with previous compounds in this series. All other proton signals in the molecule were readily assigned.

Also, in this case the product appears to be a pure single diastereoisomer, and the c.d. spectrum (Figure) indicates that it has the (5*R*) configuration. The formation of compound (**7e**) presumably involves rearrangement of the first formed acetate (**7d**) in the presence of the strong base. Studies of space-filling models demonstrate the close proximity of the 3-*O*-acetyl group and the 5-OH group in (**7d**), making such a rearrangement very

reasonable. In the related ethynyl acetate (**7c**) the 3-*O*-acetyl and 5-OH groups are well separated and transacylation is hence unlikely.

Experimental

Evaporations were carried out under water-pump vacuum with a flask temperature below 40 °C, unless otherwise stated. U.v. spectra were measured with a Unicam SP800 spectrophotometer, i.r. spectra with a Perkin-Elmer 681 spectrophotometer, ^{1}H n.m.r. (100 MHz) spectra with a JEOL JNM-MH-100 spectrometer (tetramethylsilane as internal standard) unless otherwise stated, and mass spectra with an A.E.I. MS 903 spectrometer. We thank the S.E.R.C. High Field n.m.r. service, Sheffield University, for high-resolution ^{1}H n.m.r. spectra and Dr. P. M. Scopes, Westfield College, and Dr. A. Drake, King's College, London, for c.d. spectra. Silica gel (0.05—0.2 mm, 70—270 mesh; Machery-Nagel and Co.) was used for column chromatography. T.l.c. was run on Silica Gel 60 F_{254} (0.2 mm thick) pre-coated aluminium plates (Merck) and Cellulose F_{254} (0.1 mm thick) pre-coated aluminium plates (Merck) in the systems (A) toluene–ethyl acetate (4:1); (B) toluene–ethyl acetate (2:1).

2-(1-*Hydroxypropyl*)*quinizarin* (**3**).—A solution of *leuco*-quinizarin (**1**) (0.168 g) in THF (3 cm^3) containing propanal (0.05 cm^3) at 0 °C was treated with DBN (0.1 cm^3) for 15 min under nitrogen, when t.l.c. examination (System B) after oxidation indicated the presence of one product (R_F 0.63) with the complete disappearance of the quinizarin (**1**). The brownish red reaction mixture was aerated for 10 min and the resultant deep blue solution was poured into a rapidly stirred mixture of ice (5 g) and 2M-hydrochloric acid (15 cm^3) to give a bright red solid precipitate which was collected by centrifugation, washed, and air-dried. The product, 2-(1-hydroxypropyl)quinizarin (**3**), crystallised from ethanol as needles (0.186 g, 93% yield), m.p. 158 °C. The compound was identical (m.p., mixed m.p., i.r., and mass spectra) with an authentic sample.[14]

3-O-(p-*Chlorobenzyl*)-1,2:5,6-*di*-O-*isopropylidene*-α-D-*gluco*-*furanose* (**4b**).—(*a*) To a solution of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**4a**) (30 g) in DMSO (250 cm^3) was added sodium hydride (6.9 g) and the heterogeneous mixture was stirred for 2 h at 50 °C, then *p*-chlorobenzyl chloride (37.1 g) was added and the mixture was stirred for a further 2.5 h at 50 °C. T.l.c. examination [System B] revealed the complete disappearance of starting material (R_F 0.3) and the presence of a single product (R_F 0.7). The cooled mixture was slowly poured into a stirred mixture of crushed ice–water. The product was extracted with chloroform (3 × 50 cm^3) and the combined extracts were washed with water, dried ($MgSO_4$), and evaporated repeatedly with added toluene to yield a pale straw coloured syrup of 3-*O*-(*p*-chlorobenzyl)-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**4b**) (44 g, 99% yield) pure enough for use in subsequent reactions (Found: M^+, 384, 386. $C_{19}H_{25}ClO_6$ requires *M*, 384, 386); *m/z* 369, 371 (*M* − CH_3), 125 (100%, $C_7H_6{}^{35}Cl^+$), 127 (44, $C_7H_6{}^{37}Cl^+$), and 101; $\nu_{max.}$(neat) 1 380 cm^{-1} (CMe_2); δ ($CDCl_3$; 60 MHz) 1.15—1.75 (12 H, q, 2 CMe_2), 3.9—4.45 (6 H, unresolved, 2-, 3-, 4-, and 5-H and 6-H_2), 4.66 (2 H, $OCH_2C_6H_4Cl$), 5.91 (1 H, d, 1-H), and 7.22 (4 H, C_6H_4).

(*b*) A mixture of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**4a**) (24 g), *p*-chlorobenzyl chloride (38.1 g), Drierite (20 g), and powdered potassium hydroxide (24 g) in THF (300 cm^3) was heated under gentle reflux for 24 h and vigorously stirred. Additional portions of *p*-chlorobenzyl chloride (2 × 9.5 g) and potassium hydroxide (2 × 6.0 g) were added at 15 h intervals and the reaction was allowed to continue for a further 5 h, when t.l.c. examination [System B] revealed the complete disappearance of starting material (R_F 0.3) and the emergence of a single product (R_F 0.7). The mixture was cooled and filtered through Celite, and the filtrate was evaporated to dryness (85 °C; 0.4 mmHg) to afford an amber syrup of 3-*O*-(*p*-chlorobenzyl)-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**4b**) (35 g, 98% yield), identical with the material prepared under (*a*).

3-O-(p-*Chlorobenzyl*)-1,2-O-*isopropylidene*-α-D-*gluco*-*furanose* (**5a**).—A solution of 3-*O*-(*p*-chlorobenzyl)-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**4b**) (20 g) in aqueous acetic acid (350 cm^3; 70%) was set aside for 24 h at room temp., when t.l.c. [System B] indicated that the starting material (R_F 0.7) had been completely replaced by a single product (R_F 0.14). The solution was evaporated to dryness to yield 3-*O*-(*p*-chlorobenzyl)-1,2-*O*-isopropylidene-α-D-glucofuranose (**5a**) as a clear pale yellow syrup (17.4 g, 97% yield) (Found: M^+, 344, 346. $C_{16}H_{21}ClO_6$ requires *M*, 344, 346); *m/z* 329, 331 (*M* − CH_3), 326, 323 (*M* − H_2O), 125 ($C_7H_6{}^{35}Cl^+$), and 127 ($C_7H_6{}^{37}Cl^+$); $\nu_{max.}$(neat) 3 425 (OH) and 1 380 cm^{-1} (CMe_2).

3-O-(p-*Chlorobenzyl*)-1,2-O-*isopropylidene*-α-D-xylo-*pento*-*dialdo*-1,4-*furanose* (**6a**).—To a solution of the foregoing mono-isopropylidene derivative (17.4 g) in acetic acid (350 cm^3; 70%) was added a solution of sodium metaperiodate (11.2 g) in water (120 cm^3) and the mixture was stirred for 30 min at 0 °C. The solution was diluted with water (250 cm^3) and extracted with chloroform (7 × 35 cm^3), and the combined extracts were washed with water (3 × 25 cm^3), dried ($MgSO_4$), and evaporated to dryness (< 30 °C) to afford a pale yellow syrup of 3-*O*-(*p*-chlorobenzyl)-1,2-*O*-isopropylidene-α-D-*xylo*-dialdo-1,4-furanose (**6a**) (14.8 g, 94% yield), homogeneous on t.l.c. [System B] (R_F 0.42); $\nu_{max.}$(neat) 3 460 (OH), 1 735 (CHO), and 1 380 cm^{-1} (CMe_2). This was used immediately in the next step.

(5S)-3-O-(p-*Chlorobenzyl*)-1,2-O-*isopropylidene*-5-(*quinizarin*-2-*yl*)-α-D-*xylofuranose* (**7a**).—(*a*) To a solution of *leuco*-quinizarin (**1**) (12.6 g) in methanol (250 cm^3) and THF (350 cm^3) cooled to 0 °C was added a solution of 3-*O*-(*p*-chlorobenzyl)-1,2-*O*-isopropylidene-α-D-*xylo*-pentodialdo-1,4-furanose (**6a**) (14.8 g) in methanol (35 cm^3) and aqueous sodium hydroxide (13.1 cm^3; 32%) under nitrogen. The mixture was set aside at room temperature for 2.5 h, when t.l.c. examination [System A] after oxidation showed one major product (R_F 0.5) in addition to unchanged quinizarin (R_F 0.8), plus a trace of a compound with R_F 0.63. A steady stream of air was passed through the reaction mixture for 2.5 h and the resultant purple solution was added dropwise to a rapidly stirred mixture of 2M-hydrochloric acid (250 cm^3) and crushed ice (150 g). The red solid precipitate was collected by filtration, washed with water, and air-dried. A filtered solution of the foregoing solid (14.5 g) in toluene–ethyl aceate (4:1) was applied to a silica gel column (7 × 50 cm) and eluted by the same solvent mixture (5S)-3-O-(p-*Chlorobenzyl*)-1,2-O-*isopropylidene*-5-(*quinizarin*-2-*yl*)-α-D-*xylofuranose* (**7a**) crystallised from ethanol as fine orange-red needles (8.95 g, 34%), m.p. 148 °C (Found: C, 62.75; H, 4.5; Cl, 6.55%; M^+, 552, 554. $C_{29}H_{25}ClO_9$ requires C, 63.0; H, 4.55; Cl, 6.43%; *M*, 552, 554); *m/z* 537, 539 (*M* − CH_3), 269, 240, 125 (100%, $C_7H_6{}^{35}Cl^+$), and 127 (31, $C_7H_6{}^{37}Cl^+$); $\nu_{max.}$ (KBr disc) 3 500 (OH), 1 625 and 1 590 (quinizarin), and 1 380 cm^{-1} (CMe_2); $\lambda_{max.}$(MeOH) (log ε) 482 (4.09), 250 (4.66), 222 (4.56), and 206 nm (4.55); δ* ($CDCl_3$; 400 MHz) 1.36 and 1.54 (2 × 3 H, CMe_2), 3.86 (1 H, d, $J_{5,5\text{-OH}}$ 3 Hz, 5-OH, exch. D_2O), 4.22 (1 H, d, $J_{2,1}$ 4 Hz, 2-H), 4.55 and 4.75 (2 × 1 H, d, *J* 11.5 Hz, $OCH_2C_6H_4Cl$), 4.68 (2 H, m, 3- and 4-H), 5.43 (1 H, dd, $J_{5,5\text{-OH}}$

* Primed locants refer to the quinizarin moeity.

3 Hz, 5-H), 6.04 (1 H, d, $J_{1,2}$ 4 Hz, 1-H), 7.36 (4 H, m, $OCH_2C_6H_4$), 7.63 (1 H, s 3′-H), AA′BB′ signal [δ_A 7.80—7.88 (6′-7′-H), δ_B 8.31—8.36 (5′- and 8′-H)], 12.84 (1 H, s, 4′-OH, exch. D_2O), and 13.54 (1 H, s, 1′-OH, exch. D_2O).

(*b*) To a solution of *leuco*-quinizarin (**1**) (1.69 g) in DMF (18 cm^3) cooled to 0 °C was added a solution of 3-*O*-(*p*-chlorobenzyl)-1,2-*O*-isopropylidene-α-D-*xylo*-pentodialdo-1,4-furanose (**6a**) (2.1 g) in DMF (5 cm^3) and DBN (1.73 cm^3) under nitrogen during 10 min. T.l.c. [System A] examination showed one major product (R_F 0.5) in addition to a trace of a compound with R_F 0.63 and some unchanged *leuco*-quinizarin. A steady stream of air was passed through the mixture for 30 min and the resultant purple solution was added dropwise to a rapidly stirred mixture of crushed ice and M-hydrochloric acid (25 cm^3). The resultant solid red precipitate was collected, washed with water, and air-dried. The solid was purified as described in (*a*) above to give the major product as an orange-red solid which crystallised from ethanol as fine orange-red needles (1.48 g, 40% yield). The product was identical (^1H n.m.r., mass, and i.r. spectra) with the major product (**7a**) obtained by method (*a*).

(5S)-5-O-*Acetyl*-3-O-(p-*chlorobenzyl*-5-(1,4-*diacetoxyquinizarin*-2-*yl*)-1,2-O-*isopropylidene*-α-D-*xylofuranose* (**7b**).—A solution of 3-*O*-(*p*-chlorobenzyl)-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-xylofuranose (**7a**) (0.1 g) in pyridine (7 cm^3) and acetic anhydride (4 cm^3) was set aside at room temperature for 24 h, when the solution colour had changed from orange to yellow; t.l.c. [System B] examination indicated the complete disappearance of the starting material (R_F 0.5) and the emergence of a single product (R_F 0.6). The solution was poured into ice–water and the mixture was extracted with chloroform (3 × 15 cm^3). The organic fractions were combined, washed with water, dried ($MgSO_4$), and evaporated to leave a yellow solid. The *triacetate* (**7b**) (0.1 g, 81% yield) had m.p. 185 °C (Found: C, 61.8; H, 4.6; Cl, 5.0. $C_{35}H_{31}ClO_{12}$ requires C, 61.95; H, 4.61; Cl, 5.23%); *m/z* 636, 638 (*M* − C_2H_2O), 594, 596 (*M* − 2 × C_2H_2O), 534, 536 (*M* − 2 × C_2H_2O − H_2O), 311 (Q − CH−$OCOCH_3$), 269 (*Q* − CH: $\overset{+}{O}H$), and 125 ($C_7H_6{}^{35}Cl^+$, 100%); $\lambda_{max.}$(MeOH), 273, 254, and 220 nm; δ ($CDCl_3$; 400 MHz) 1.33 and 1.55 (2 × 3 H, CMe_2), 2.0 (3 H, s, 5-$COCH_3$), 2.35—2.55 (6 H, m, 1′- and 4′-OAc), 3.62 (1 H, 3- or 4-H), 4.05 and 4.4 (2 × 1 H, OCH_2), 4.56 (1 H, d, $J_{2,1}$ 2 Hz, 2-H), 4.64—5.1 (1 H, 4- or 3-H), 6.05 (1 H, d, $J_{1,2}$ 2 Hz, 1-H), 6.1 (1 H, d, 5-H), 7.15 and 7.35 (2 × 2 H, C_6H_4Cl), 7.25 (1 H, s, 3′-H), and AA′BB′ signal [δ_A 7.7—7.8 (6′- and 7′-H), δ_B 8.1—8.28 (5′-and 8′-H)].

2′-[3-O-(p-*Chlorobenzyl*)-1,2-O-*isopropylidene*-α-D-*xylofuranuronyl*]*quinizarin* (**8**).—Pyridinium chlorochromate (0.156 g, 3.5 mol equiv.) was added to a solution of (5*S*)-3-*O*-(*p*-chlorobenzyl)-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-xylofuranose (**7a**) (0.1058 g) in dry dichloromethane (50 cm^3) and the mixture was stirred at room temperature for 24 h, when t.l.c. revealed complete disappearance of starting material and the presence of a single product. The solution was filtered, diluted with dichloromethane to ~75 cm^3, and washed with saturated aqueous hydrogen carbonate (2 × 100 cm^3) and then with water until the aqueous extracts were colourless. The reddish brown solution was dried (Na_2SO_4), filtered through Celite, and evaporated to give a red gum. The residue was dissolved in toluene–ethyl acetate (4:1, 25 cm^3) and filtered slowly through a pad of silica gel on a sintered glass funnel. The red filtrate (homogeneous on t.l.c.) was evaporated to dryness and the oxo derivative (**8**) crystallised from alcohol as orange-red needles, m.p. 178 °C (Found: M^+, 550, 552. $C_{29}H_{23}ClO_9$ requires *M*, 550, 552); *m/z* 535, 537 (*M* − CH_3), 492, 494 (*M* − Me_2CO), 267 (*Q* − CO^+, 100%) and 125, 127 ($C_7K_6Cl^+$, 83 and 31); $\nu_{max.}$(KBr) 1 705 (C=O), 1 630 and 1 590 (quinone), and 1 380 cm^{-1} (CMe_2).

(5S)-3-O-(p-*Chlorobenzyl*)-5-(*quinizarin*-2-*yl*)D-xylo-*hexopyranose* (**9**).—A solution of (5*S*)-3-*O*-(*p*-chlorobenzyl)-1,2-*O*-isopropylidene-5-(quinizarin-2-yl)-α-D-xylofuranose (**7a**) (2 g) in aqueous acetic acid (250 cm^3; 70%) was held at reflux for 2 h, when t.l.c. [SystemB] revealed the complete disappearance of starting material (R_F 0.66) and the presence of a single product (R_F 0.14). The solution was evaporated to dryness and added toluene was repeatedly evaporated to give a red solid residue of (5S)-3-O-(p-*chlorobenzyl*)-5-(*quinizarin*-2-*yl*)-D-xylo-*pyranose* (**9**) (1.8 g, 97%), m.p. 212 °C (Found: C, 60.8; H, 4.1; Cl, 6.5%; M^+, 512, 514. $C_{26}H_{21}ClO_9$ requires C, 60.88; H, 4.13; Cl, 6.9%; *M*, 512, 514); *m/z* 496, 494 (*M* − H_2O), 369 (*M* − H_2O − $C_7H_6Cl^+$), 269, 240, and 125 (100%, $C_7H_6Cl^+$); δ [$(CD_3)_2SO$; 400 MHz] 3.3—3.5 (2 H, m, 2-and 3-H), 3.7 (1 H, t, $J_{4,5}$ 10 Hz, 4-H), 4.57 (1 H, t, $J_{1,1\text{-OH}}$ 6.5 Hz, 1-H), 4.73 (1 H, d, $J_{5,4}$ 10 Hz, 5-H), 4.84 (2 H, dd, *J* 10.5 Hz, CH_2Ph), 5.28—5.32 (2 H, 2- and 4-OH, both exch. D_2O), 6.95 (1 H, $J_{1\text{-OH},1}$ 6.5 Hz, 1-OH), 7.38 and 7.46 (2 × 2 H, 2 × d, $OCH_2C_6H_4$), 7.51 (1 H, s, 3′-H), AA′BB′ signal [δ_A 7.95—8.1 (6′- and 7′-H), δ_B 8.23—8.29 (5′- and 8′-H)], and 12.8 and 13.4 (2 × 1 H, both s, 1′- and 4′-OH, both exch. D_2O).

(4S)-2-O-(p-*Chlorobenzyl*)-4-(*quinizarin*-2-*yl*)-D-threo-*pentofuranose* (**11**).—To a solution of the foregoing xylose derivative (**9**) (1.8 g) in aqueous acetic acid (300 cm^3; 60%) was added a solution of sodium metaperiodate (0.8 g) in water (50 cm^3) and the mixture was stirred for 20 min. T.l.c. examination [System B] indicated the presence of three products (R_F 0.47, 0.61, and 0.26) with the complete disappearance of starting material (R_F 0.11). Water (200 cm^3) was added and the mixture was extracted with chloroform (5 × 30 cm^3). The organic fractions were combined, washed with water (3 × 25 cm^3), dried ($MgSO_4$), and evaporated to afford a dark red solid which was dissolved in 1M-aqueous sodium hydroxide, followed by acidification to give a solid precipitate which was collected. The precipitate consisted of two major products (R_F 0.4) and (R_F 0.26) with the complete absence of the product with R_F 0.61 [probably the formyl ester (**10**)]. A filtered solution of the solid in toluene–ethyl acetate (2:1) was applied to a silica gel column (7 × 15 cm) and eluted by the same solvent mixture to give (4S)-2-O-(p-*chlorobenzyl*)-4-(*quinizarin*-2-*yl*)-D-threo-*pentofuranose* (**11**) (0.57 g, 34%) (R_F 0.26) which crystallised from toluene as orange needles, m.p. 190 °C (Found: C, 62.1; H, 3.9; Cl, 7.3%; M^+, 482, 484. $C_{25}H_{19}ClO_8$ requires C, 62.18; H, 3.96; Cl, 7.35%; *M*, 482, 484); *m/z* 464 (M^+ − H_2O), 446 (M^+ − $2H_2O$), 269, 240, and 125, 127 ($C_7H_6Cl^+$, 100 and 34%); $\lambda_{max.}$(MeOH) 207, 223, 251, and 287 nm; [$(CD_3)_2SO$; 400 MHz] 3.72 (1 H, m, 2-H), 4.16 (1 H, br s, 4-H), 4.54 and 4.63 (2 × 1 H, d, *J* 12 Hz, $OCH_2C_6H_4Cl$), 5.07 and 5.31 (1 H, d, signal split in ratio 5:1, *J* 6 Hz, 1-H), 5.5 (1 H, q, 3-H), 5.63 (1 H, br s, 3-OH, exch. D_2O), 6.84 and 6.58 (1 H, d, *J* 6 Hz, 1-OH), 7.28—7.36 (4 H, m, $OCH_2C_6H_4$), 7.74 (1 H, s, 3′-H), AA′BB′ signal [δ_A 7.95—8.0 (6′- and 7′-H), δ_B 8.22—8.27 (5′- and 8′-H)], and 12.7 and 13.2 (2 × 1 H, 1′- and 4′-OH, exch. D_2O).

Further elution then gave 2-O-(p-*chlorobenzyl*)-3-*deoxy*-4-(*quinizarin*-2-*yl*)-L-glycero-*tetr*-3-*enofuranose* (**12**) (0.85 g, 52%) (R_F 0.47) which was isolated as a hydrated orange-red solid, m.p. 195 °C (Found: C, 61.3, H, 3.9; Cl, 7.3%; M^+, 464, 466. $C_{25}H_{17}ClO_7 \cdot 1.5H_2O$ requires C, 61.04; H, 4.1; Cl, 7.2%; *M*, 464, 466); *m/z* 269, 240, and 125, 127 ($C_7H_6Cl^+$, 100 and 36%); δ [$(CD_3)_2SO$; 270 MHz] 3.8 (1 H, m, 2-H), 4.6 and 4.7 (2 H, m, OCH_2), 5.2 and 5.5 (1 H, d, split 2:3, 1-H), 6.5 (1 H, d, 1-OH, exch. D_2O), 7.35 (1 H, s, 3′-H), 7.44 (5 H, m, C_6H_4Cl and 3-H), AA′BB′ signal [δ_A 7.95—8.0 (6′- and 7′-H), δ_B 8.2—8.3 (5′- and

8′-H)], and 12.77 and 13.2 (2 × 1 H, 1′- and 4′-OH, each exch. D_2O).

The ^1H n.m.r. spectra data are consistent with compounds (**11**) and (**12**) each being mixtures of the α- and β-isomer.

(7RS,8S,9S,10S)-8-(p-*Chlorobenzyloxy*)-7,8,9,10-*tetrahydro*-6,7,9,10,11-*pentahydroxynaphthacene*-5,12-*dione* (**14a**).—A solution of (4*S*)-2-*O*-(*p*-chlorobenzyl)-4-(quinizarin-2-yl)-D-*threo*-pentofuranose (**11**) (0.5 g) in methanol (10 cm^3) and THF (8 cm^3) was cooled to 0 °C and treated with 1M-aqueous sodium hydroxide (8 cm^3), containing sodium dithionite (0.5 g), for 45 min under nitrogen. T.l.c. [System B] showed the absence of starting material (R_F 0.2), the presence of one major product (R_F 0.27), and a second component (R_F 0.14) in addition to a trace of another material. The solution was aerated for 20 min and then acidified with 2M-hydrochloric acid to afford a red solid precipitate (0.4 g), which was collected, washed well with water, and air-dried. The products were isolated using thick-layer (20 × 20 cm plates) chromatography with toluene–ethyl acetate (2:1) as the eluting solvent. The major product (R_F 0.27), (7RS,8S,9S,10S)-8-(p-*chlorobenzyloxy*)-7,8,9,10-*tetrahydro*-6,7,9,10,11-*pentahydroxynaphthacene*-5,12-*dione monohydrate* (**14a**), crystallised from toluene as orange-red needles (0.189 g, 38%), m.p. 240 °C (Found: C, 59.8; H, 3.8%; M^+, 482, 484. $C_{25}H_{19}ClO_8 \cdot H_2O$ requires C, 59.94; H, 3.8%; *M*, 482, 484); *m/z* 464 and 466 ($M - H_2O$), 446 and 448 ($M - 2H_2O$), 322 ($M - H_2O - OCH_2C_6H_4Cl$), 298 (retro-Diels–Alder fragment), and 125 ($C_7H_5{}^{35}Cl^+$, 100%); $\lambda_{max.}$(MeOH) 208, 226, 286, and 450—550 nm (characteristic for a 2,3-disubstituted quinizarin); δ[$(CD_3)_2SO$] 3.8 (1 H, dd, 8- or 9-H) 4.0 and 4.1 (1 H, m, signal split in ratio 4:1, 9- or 8-H), 4.7 and 4.83 (2 × 1 H, d, *J* 12 Hz, $OCH_2C_6H_4$), 4.93 (1 H, d, *J* 6.5 Hz, 10-OH, exch. D_2O), 4.98 and 5.21 (2 × 1 H, d, $J_{7,8} = J_{9,10} = 3.5$ Hz, 7- and 10-H), 5.37 (2 × 1 H, br, 7- and 9-OH, exch. D_2O), 7.42 and 7.55 (2 × 2 H, C_6H_4Cl), AA′BB′ signal [δ_A 7.96—8.1 (2- and 3-H), δ_B 8.27—8.31 (1- and 4-H)], and 13.45 (2 × 1 H, br s, 6- and 11-OH, exch. D_2O).

(8S,9S,10S)-8-(p-*Chlorobenzyloxy*)-7,8,9,10-*tetrahydro*-6,9,10,11-*tetrahydroxynaphthacene*-5,12-*dione* (**14b**).—The fraction (R_F 0.14) from the foregoing experiments was obtained as a shiny red crystalline precipitate upon evaporation of the appropriate fraction. The product was identified as (8S,9S,10S)-8-(p-*chlorobenzyloxy*)-7,8,9,10-*tetrahydro*-6,9,10,11-*tetrahydroxynaphthacene*-5,12-*dione monohydrate* (**14b**) (0.123 g, 26%), m.p. 225 °C (Found: C, 62.2; H, 4.0%; M^+, 466, 468. $C_{25}H_{19}ClO_7 \cdot H_2O$ requires C, 61.92; H, 4.35%; *M*, 466, 468); *m/z* 448, 450 ($M - H_2O$), 322, 306 ($M - C_7H_7OCl^+ - H_2O$), 125 ($C_7H_6{}^{35}Cl^+$, 100%), and 127 ($C_7H_6{}^{37}Cl^+$, 30); $\lambda_{max.}$(MeOH) 208, 226, 286, and 450—550 nm (characteristic of a 2,3-disubstituted quinizarin); δ ($CDCl_3$; 400 MHz) 3.23 and 3.92 (2 × 1 H, br s, 9- and 10-OH, exch. D_2O), 4.15 (1 H, m, 8-H), 4.2—4.25 (2 × 1 H, m, $J_{7ax,7eq}$ 12, $J_{7ax,8}$ or $J_{7eq,8}$ 4.5 Hz, 7-H_{ax} and 7-H_{eq}), 4.72 and 4.91 (2 × 1 H, d, *J* 12 Hz, OCH_2), 5.12 (1 H, m, *J* 4.5 and 1.5 Hz, 9-H), 5.29 (1 H, d, *J* 4 Hz, 10-H), 7.33 (4 H, m, C_6H_4Cl), AA′BB′ signal [δ_A 7.83—7.89 (2- and 3-H), δ_B 8.34—8.39 (1-and 4-H)], and 13.0—13.7 (2 × 1 H, m, 6- and 11-OH, exch. D_2O).

3-O-*Acetyl*-3-C-*ethynyl*-1,2:5,6-*di*-O-*isopropylidene*-α-D-*allofuranose* (**4d**).—To a solution of 3-*C*-ethynyl-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose[15] (**4c**) (3.5 g) in dry pyridine (50 cm^3) was added acetic anhydride (35 cm^3) and the mixture was set aside at room temperature for 24 h. T.l.c. examination [System B] revealed the complete disappearance of starting material (R_F 0.29) and the presence of a single product (R_F 0.55). The reaction mixture was poured slowly into rapidly stirred water (250 cm^3) to give a white precipitate which was collected, washed well with water, and air-dried. 3-O-*Acetyl*-3-C-*ethynyl*-1,2:5,6-*di*-O-*isopropylidene*-α-D-*allofuranose* (**4d**) crystallised from aqueous pyridine as needles (3.2 g, 80%), m.p. 82 °C; *m/z* 311 ($M - CH_3$), 101, and 42 ($COCH_3$, 100%); $\nu_{max.}$ 1 745 (C=O), 1 380 (CMe_2), and 2 110 cm^{-1} (C≡C); δ ($CDCl_3$; 60 MHz) 1.35 and 1.55 (2 × 6 H, 2 CMe_2), 2.15 (3 H, s, OCH_3), 2.78 (1 H, s, C≡CH), 5.15 (2 H, m, 2- and 5-H), 4.1—4.5 (3 H, m, 4-H and 6-H_2), and 5.9 (1 H, d, 1-H).

3-O-*Acetyl*-3-C-*ethynyl*-1,2-O-*isopropylidene*-5-(*quinizarin*-2-*yl*)-α-D-*ribofuranose* (**7c**).—A solution of 3-*O*-acetyl-3-*C*-ethynyl-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose (**4d**) (3.2 g) in acetic acid (100 cm^3; 70%) was left at room temperature for 24 h, when t.l.c. examination [System B] indicated the presence of one major product (R_F 0.1) with complete disappearance of starting material (R_F 0.55). To the solution at 0 °C was added a solution of sodium metaperiodate (2.3 g, 1.1 mol equiv.) in water (30 cm^3) and the mixture was stirred for 40 min, when t.l.c. examination [System B] indicated the presence of one product (R_F 0.23). The reaction was quenched by the addition of water (150 cm^3) and the product was extracted into chloroform (3 × 50 cm^3). The combined extracts were washed with water (3 × 50 cm^3), dried ($MgSO_4$), and evaporated to yield a clear pale yellow syrup of the aldehyde (**6b**) (2.4 g, 96% yield), $\nu_{max.}$ 1 380 (Me_2C) and 1 735 cm^{-1} (CHO).

To a solution of *leuco*-quinizarin (**1**) (2.62 g) in DMF (35 cm^3) was added a solution of the aldehyde (**6b**) (2.4 g) in DMF (15 cm^3) and the mixture was treated with DBN (3.35 cm^3) under nitrogen at 0 °C for 25 min. T.l.c. examination [System B] after oxidation showed the presence of one major product (R_F 0.5) in addition to a minor product (R_F 0.65) and *leuco*-quinizarin (**1**) (R_F 0.8). A steady stream of moisture-free air was passed through the reaction mixture for 30 min and the resultant purple-blue solution was poured into a rapidly stirred mixture of 2M-hydrochloric acid (50 cm^3) and crushed ice (50 g). The resultant red solid precipitate (3.7 g) was collected, washed well with water, and air-dried. A filtered solution of the product in toluene–ethyl acetate (2:1) was applied to a silica gel column by the same solvent mixture. The major product (R_F 0.5) was separated from *leuco*-quinizarin (**1**) and the minor product, and obtained in solid form upon evaporation of the appropriate fractions.

(*a*) The major product (5RS)-3-O-*acetyl*-3-C-*ethynyl*-1,2-O-*isopropylidene*-5-(*quinizarin*-2-*yl*)-α-D-*ribofuranose* (**7c**) (1.35 g, 30% yield), crystallised from ethanol as needles, m.p. 182 °C, which retained water (Found: C, 62.4; H, 4.5%; M^+ 494. $C_{26}H_{22}O_{10} \cdot \frac{1}{4}H_2O$ requires C, 62.58; H, 4.54%; *M*, 494); *m/z* 479 ($M - CH_3$), 434 ($M - CMe_2 - H_2O$), 419 ($M - CMe_2 - H_2O - CH_3$), 269, 240, and 167 (100%); $\nu_{max.}$ 3 500 (OH), 3 290 (C≡CH), 2 990 (CH), 2 105 (C≡C), 1 755 (C=O), 1 625 and 1 590 (quinone absorptions), and 1 380 cm^{-1} (CMe_2); $\lambda_{max.}$(MeOH) 450, 286, 208, and 204 nm; δ ($CDCl_3$; 400 MHz) 1.3 and 1.5 (6 H, CMe_2), 1.9 and 2.1 (3 H, s, CH_3, signal split in the ratio 2.5:1), 2.9 (1 H, signal split, C≡CH), 3.5 (1 H, br s, 5-OH, exch. D_2O), 4.65 (1 H, d, *J* 8 Hz, 4-H), 5.2 (1 H, d, signal split ratio ~ 1:2.5, *J* 3 Hz, 2-H), 5.3—5.35 (1 H, d, signal split in ratio 2.5:1, *J* 8 Hz, 5-H), 5.9—6.0 (1 H, d, signal split in ratio 2.5:1, *J* 3.5 Hz, 1-H), 7.4—7.5 (1 H, s, signal split in ratio ~ 2.5:1, 3′-H), AA′BB′ signal [δ_A 7.75—7.78 (6′- and 7′-H), δ_B 8.21—8.28 (5′- and 8′-H)], 12.75 (1 H, s, split 1:2.5, 4′-OH, exch. D_2O), and 13.55—13.6 (1 H, s, split 1:2.5, 1′-OH, exch. D_2O). The ^1H n.m.r. spectrum suggests that the compound is a mixture of the two C-5 epimers in the ratio 1:2.5.

(*b*) The minor product from the reaction (R_F 0.65, System A), (5RS)-3-C-*ethynyl*-3-*deoxy*-1,2-O-*isopropylidene*-5-(*quinizarin*-2-*yl*)-α-D-glycero-*pent*-3-*enefuranose* (**13**), crystallised from toluene as deep red needles, m.p. 160 °C, which retained toluene (Found: C, 68.4; H, 4.6%; M^+, 434. $C_{24}H_{18}O_8 \cdot \frac{1}{2}C_7H_8$ requires

C, 68.75; H, 4.6%; *M*, 434); *m/z* 405 and 269 ($Q - \overset{+}{C}HOH$, 100%); δ ($CDCl_3$; 400 MHz) 1.45 and 1.55 (2 × 3 H, CMe_2), 3.24 (1 H, s, C≡CH), 3.30 (1 H, d, $J_{5\text{-}OH,5}$ 7 Hz, 5-OH, exch. D_2O), 5.29 (1 H, d, $J_{2,1}$ 5 Hz, 2-H), 5.90 (1 H, d, $J_{5,5\text{-}OH}$ 7 Hz, 5-H), 6.05 (1 H, d, $J_{1,2}$ 5 Hz, 1-H), 7.55 (1 H, s, 3′-H), AA′BB′ signal [δ_A 7.81—7.86 (6′- and 7′-H), δ_B 8.30—8.50 (5′- and 8′-H)], 12.9 (1 H, s, 4′-OH, exch. D_2O), and 13.4 (1 H, s, 1′O-H, exch. D_2O).

(5R)-5-O-*Acetyl*-1,2-O-*isopropylidene*-5-(*quinizarin*-2-*yl*)-α-D-*xylofuranose* (**7e**).—A solution of 3-*O*-acetyl-1,2-*O*-isopropylidene-α-D-*xylo*-pentodialdo-1,4-furanose (**6c**) (4 g) in DMF (60 cm^3) was added to a solution of *leuco*-quinizarin (**1**) (5 g) in DMF (60 cm^3) under nitrogen at −6 °C. After 30 min, DBN (6 cm^3) was added and after a further 30 min the mixture was aerated for 30 min then poured into iced 2M-hydrochloric acid (1 l) and the red solid precipitate was collected, washed with water, and air-dried. The mixture was purified by chromatography on silica gel using toluene–ethyl acetate (4:1) as the eluting solvent, and the major product (R_F 0.3; System A) was isolated. The O-*acetyl derivative* (**7e**) (28%) crystallised from toluene–ethyl acetate as orange-red needles, m.p. 190 °C (Found: C, 61.0; H, 4.7%; M^+, 470. $C_{24}H_{22}O_{10}$ requires C, 61.27; H, 4.7%; *M*, 470); *m/z* 269 ($Q - \overset{+}{C}HOH$) and 240; $\nu_{max.}$ 3 500 (OH), 1 750 (COMe), 1 630, 1 595 (quinone), and 1 385 cm^{-1} (CMe_2); δ ($CDCl_3$; 400 MHz) 1.3, 1.5 (6 H, CMe_2), 2.22 (3 H, s, MeCO), 4.57 (1 H, d, $J_{2,1}$ 3.5 Hz, 2-H), 4.7 (1 H, m, 3-H), 5.05 (1 H, br d or dd becoming a sharp d with D_2O, *J* 8.5 Hz, 4-H), 5.38 (1 H, d, *J* 2.5 Hz, 5-H), 5.67 (1 H, s, 3-OH, exch. D_2O) 5.95 (1 H, d, $J_{1,2}$ 3.5 Hz, 1-H), 7.42 (1 H, s, 3′-H), AA′BB′ signal [δ_A 7.8—7.9 (6′- and 7′-H), δ_B 8.3—8.4 (5′- and 8′-H)], 12.81 (1 H, s, 1′-OH, exch. D_2O), and 13.61 (1 H, s, 4′-OH, exch. D_2O).

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