Pigments of *Gnomonia erythrostoma*. Part III.[1] Synthesis of a Methyl Ether of Bisdeoxyerythrostominone

By **Brian E. Cross** * and **Leslie J. Zammitt**, Department of Organic Chemistry, University of Leeds, Leeds LS2 9JT

The structure of the ring system and the position of six of the seven oxygen functions in deoxyerythrostominone have been confirmed by the total synthesis of (±)-2-acetonyl-3,4-dihydro-6,8-dimethoxy-2*H*-naphtho[2,3-*b*]-pyran-5,10-quinone (20). Compound (20) has also been obtained by methylation of a hydrogenation product of erythrostominone.

ERYTHROSTOMINONE and deoxyerythrostominone have been shown [2] to have structures (1) and (2), respectively. Since the position of the methoxy-group at C-8 could not be rigorously proven by degradation and spectro-

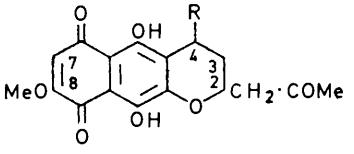
[1] Part II, B. E. Cross and L. J. Zammitt, *J.C.S. Perkin I*, 1973, 2975.

[2] B. E. Cross, M. N. Edinberry, and W. B. Turner, *J.C.S. Perkin I*, 1972, 380.

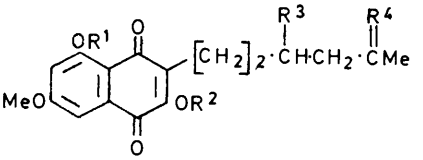
scopy, synthetic approaches to deoxyerythrostominone have been explored. First, the position of the methoxy-group was established by synthesis of the 2-(5-oxohexyl)-1,4-naphthoquinone (3) which had previously [2] been obtained by degradation of erythrostominone.

In a model reaction, methyl 3,5-dimethoxyphenylacetate was condensed with heptanoyl chloride to give a route to derivatives of deoxyerythrostominone. The octanoic acid requires an additional functional group at C-5 or C-6, such that after formation of the naphthoquinone, it can cyclise onto the 3-hydroxy-group to form the pyran ring of the pigments.

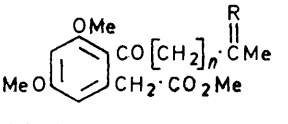
Bromination [6] of 7-oxo-octanoic acid gave a mixture of the 6- and 8-bromo-isomers in the ratio of 7 : 3.



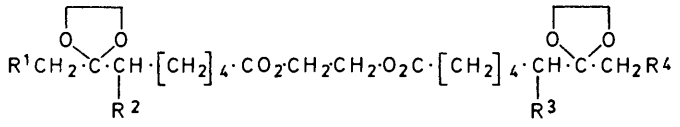
(1) R = OH
(2) R = H



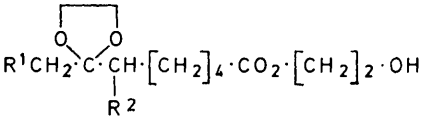
	R¹	R²	R³	R⁴
(3)	Me	Me	H	O
(4)	Me	H	H	H_2
(5)	Me	H	H	O
(6)	Me	Me	H	O
(7)	Me	H	OEt	O
(8)	Me	Et	OH	O
(9)	H	H	H	O
(10)	H	H	H	H,OH



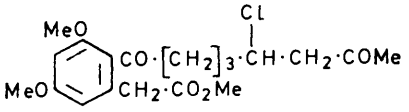
(11) R = H_2, n = 4
(12) R = O, n = 5



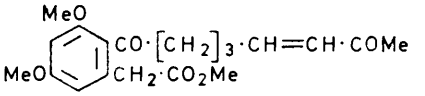
	R¹	R²	R³	R⁴
(13)	Br	H	H	Br
(14)	Br	H	Br	H
(15)	H	Br	Br	H



	R¹	R²
(16)	Br	H
(17)	H	Br



(18)



(19)

product containing (g.l.c.) 80% of the required oxo-ester (11) (*cf.* ref. 3). Cyclisation of the oxo-ester with sodium ethoxide in ethanol followed by aerial oxidation [3] gave the naphthoquinone (4), thus proving that acylation of methyl 3,5-dimethoxyphenylacetate had taken place at the 2-position. In a parallel reaction sequence the dimethoxy-ester and 7-oxo-octanoyl chloride [4,5] were condensed to yield a product containing (g.l.c.) *ca.* 20% of the oxo-ester (12) and *ca.* 80% of the unchanged dimethoxy-ester. Treatment of the mixture with base, followed by aerial oxidation, afforded the quinone (5), which on methylation gave the trimethoxy-derivative (6) identical (m.p., i.r., and u.v. spectra) with a sample prepared by degradation of erythrostominone.[2] Hence the methoxy-group in the *G. erythrostoma* pigments must be at C-8.

The synthesis described above has been extended, by modification of the aliphatic component, to provide a

Although the pure 8-bromo-acid could be crystallised from the mixture at −20 °C, the pure 6-bromo-acid was not obtained. Attempts to eliminate hydrogen bromide from the mixture of bromo-acids were unsuccessful; for example lithium chloride in dimethylformamide replaced the bromine atoms with chlorine. However, treatment of the mixed bromo-acids with ethylene glycol and toluene-*p*-sulphonic acid gave a mixture of acetal esters, believed to contain (see Experimental section) the diesters (13)—(15) and possibly the monoesters (16) and (17). Reaction of the mixture of esters with potassium t-butoxide in dimethyl sulphoxide [7] afforded the ethylene acetal of 8-bromo-7-oxo-octanoic acid and the required 7-oxo-oct-5-enoic acid. During reaction of the latter acid with oxalyl chloride some addition of hydrogen chloride to the double bond took place; consequently the unsaturated acid was treated with hydrogen chloride

[3] B. W. Bycroft and J. C. Roberts, *J. Chem. Soc.*, 1962, 2063.
[4] C. R. Hauser, F. W. Swamer, and B. I. Ringler, *J. Amer. Chem. Soc.*, 1948, **70**, 4023.
[5] R. Jaeger and R. Robinson, *Tetrahedron*, 1961, **14**, 320.
[6] J. R. Catch, D. H. Hey, E. R. H. Jones, and W. Wilson, *J. Chem. Soc.*, 1948, 276.
[7] P. E. Eaton, *J. Amer. Chem. Soc.*, 1962, **84**, 2344.

and then converted into 5-chloro-7-oxo-octanoyl chloride. The acid chloride was condensed with methyl 3,5-dimethoxyphenylacetate using perchloric acid as catalyst, to give the chloro-ketone (18) containing (as shown by its n.m.r. and mass spectra) a small amount of the unsaturated ketone (19). Cyclisation of the chloro-ketone in base followed by aerial oxidation gave a crude mixture from which the (±)-quinone (20) was isolated. Elimination of hydrogen chloride from the side chain must take place during the cyclisation in base; after oxidation to the quinone, the phenoxide ion derived from the 3-hydroxy-group and the αβ-unsaturated ketone function in the side chain presumably undergo Michael addition to give the required pyran ring. The quinone (20) was identical [i.r. ($CHBr_3$), u.v., n.m.r., and mass spectra] with the methyl ether of the (+)-bisdeoxy-quinone (21) prepared from erythrostominone (see later). The total synthesis of the quinone (20) rigorously establishes the structure of the ring system in the *G. erythrostoma* pigments and confirms the position of six of the seven oxygen functions in deoxyerythrostominone.

A minor by-product from the preparation of the quinone (20) was another quinone, $C_{20}H_{24}O_7$, which was tentatively assigned the structure (7), since its n.m.r. spectrum revealed an ethoxy-group (see Experimental section) and its mass spectrum showed a strong peak at *m/e* 330 (*M* − EtOH). Structure (7) is proposed in preference to structure (8) because the u.v. spectrum of the ethoxy-quinone is very similar to that of the 3-hydroxy-quinone (5), but differs from that of the 3-methoxy-quinone (6).[2]

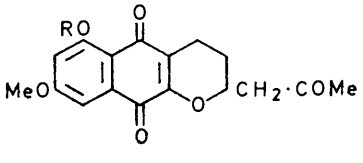
The prolonged hydrogenation of erythrostominone is known [2] to give a mixture of bisdeoxy-quinones. Repetition of this work followed by multidevelopment p.l.c. afforded five main bands. The front-running band contained the quinone (9).[2] The pure bisdeoxyquinone (21) was obtained from the second band and was identified by its n.m.r. spectrum (see Experimental section) which, in particular, contained doublets due to *meta*-coupled aromatic protons. Methylation of this quinone gave the methyl ether (20), identical with a synthetic sample (see above).

The third band from the p.l.c. yielded an isomeric bisdeoxy-quinone, which on the basis of its spectroscopic data (see Experimental section), was assigned structure (22) and/or (23). Later bands from the p.l.c. gave deoxyerythrostominone (2) [2] and a mixture of trihydroxy-quinones believed from their spectroscopic data (see Experimental section) to contain the quinone (10) [2] together with its isomers (24) and/or (25).

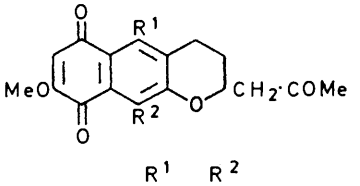
An attempt to repeat the preparation of 7-hydroxy-5-oxo-octanoic acid from the *N*-methylamide (26) by the method of Lukeš and Černý [8] gave, not unexpectedly, 5-oxohexanoic acid,[9] which presumably arose by retro-aldol fission.

EXPERIMENTAL

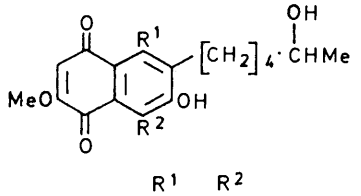
Details of chromatographic materials and conditions used for the determination of physical data *etc.* have been reported.[1,2] G.l.c. was carried out at 165—185 °C on a Varian 1527B chromatograph (150 cm column packed with 5% SE30 on 80—90 mesh Anakrom). Spectroscopic data of compounds marked with an asterisk are unexceptional and are listed in Supplementary Publication No. SUP 21459 (3 pp.).†



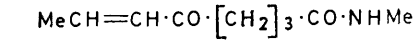
	R
(20)	Me
(21)	H



	R^1	R^2
(22)	H	OH
(23)	OH	H



	R^1	R^2
(24)	H	OH
(25)	OH	H



(26)

Methyl 3,5-*Dimethoxy*-2-(1-*oxoheptyl*)*phenylacetate*.—Perchloric acid (70%; 5 drops) was added to a mixture of methyl 3,5-dimethoxyphenylacetate [3] (1.34 g) and heptanoyl chloride (3.0 g) which was stirred for 70 h at room temperature. Recovery in ether gave an oil (1.60 g), shown by g.l.c. to contain 20% of starting ester and 80% of methyl 3,5-dimethoxy-2-(1-oxoheptyl)phenylacetate* (11) (Found: *m/e* 322.1773. Calc. for $C_{18}H_{26}O_5$: *M*, 322.1780).

3-*Hydroxy*-6,8-*dimethoxy*-2-*pentyl*-1,4-*naphthoquinone*.—The above oxo-ester (600 mg) (containing 20% of methyl 3,5-dimethoxyphenylacetate) was added dropwise to a refluxing solution of sodium (60 mg) in ethanol (8 ml) which was boiled for 20 min. The solution was cooled and air was bubbled through it for 4 h, during which time it became deep red in colour. Evaporation *in vacuo* left a residue which was treated with N-sulphuric acid (25 ml), and the resultant yellow solid was collected and dissolved in N-sodium hydroxide. The solution was washed with ether and neutralised with N-sulphuric acid, and the precipitate was recovered in ether and crystallised from ether as yellow needles (150 mg), m.p. 155—157°, of 3-*hydroxy*-6,8-*dimethoxy*-2-*hexyl*-1,4-*naphthoquinone** (4) (Found: C, 67.3;

† For details of Supplementary Publications see Notice to Authors No. 7, *J.C.S. Perkin I*, 1974, Index issue.

[8] R. Lukeš and M. Černý, *Coll. Czech. Chem. Comm.*, 1959, **24**, 2722.

[9] W. H. Bentley and W. H. Perkin, *J. Chem. Soc.*, 1896, **69**, 1511.

H, 6.5%; *m/e* 304. $C_{17}H_{20}O_5$ requires C, 67.1; H, 6.6%; *M*, 304).

This cyclisation was also affected with potassium t-butoxide in t-butyl alcohol.

Methyl 2-(1,7-Dioxo-octyl)-3,5-dimethoxyphenylacetate.—7-Oxo-octanoic acid [4] (b.p. 130—134° at 0.8 mmHg) was converted into its acid chloride with oxalyl chloride.[5] Perchloric acid (70%; 6 drops) was added to a mixture of the methyl 3,5-dimethoxyphenylacetate (1.40 g) and 7-oxo-octanoyl chloride (3.75 g) in benzene (2 ml) under nitrogen and stirred for 15 h at 20 °C. Recovery gave an oil which was shown (g.l.c. and n.m.r. spectrum) to contain 20% of methyl 2-(1,7-dioxo-octyl)-3,5-dimethoxyphenylacetate* (12) (Found: *m/e* 350.1746. Calc. for $C_{19}H_{26}O_6$: *M*, 350.1729).

3-Hydroxy-6,8-dimethoxy-2-(5-oxohexyl)-1,4-naphthoquinone.—The dioxo-ester (12) (containing *ca.* 80% of methyl 3,5-dimethoxyphenylacetate) (2.01 g) in ethanol (20 ml) was added to a solution of sodium (240 mg) in ethanol (30 ml) and refluxed for 20 min. Aerial oxidation and recovery as described above gave an oil which was chromatographed on Kieselgel G (200 g). Elution with benzene–ethanol (23 : 2) afforded *3-hydroxy-6,8-dimethoxy-2-(5-oxohexyl)-1,4-naphthoquinone* (5), which crystallised from ethanol as golden plates (116 mg), m.p. 190—193° (Found: C, 64.8; H, 6.05%; *m/e* 332. $C_{18}H_{20}O_6$ requires C, 65.05; H, 6.1%; *M*, 332), $\nu_{max.}$ 3 410, 1 710, 1 655sh, and 1 643 cm^{-1}; $\lambda_{max.}$ 215, 261, 304, 367, and 410sh nm (ε 32 300, 21 300, 11 200, 4 090, and 1 880); τ 8.34 (4 H, m, 2′- and 3′-H_2), 7.87 (3 H, s, 6′-H_3), 7.48 (4 H, m, 1′- and 4′-H_2), 6.05 (3 H, s, OMe), 6.03 (3 H, s, OMe), 3.23 (1 H, d, *J* 2.0 Hz, 7-H), 2.96br (1 H, 3-OH), and 2.74 (1 H, d, *J* 2.0 Hz, 5-H).

Its methyl ether, prepared with silver oxide and methyl iodide in chloroform, formed yellow needles, m.p. 128—130°, identical (t.l.c., i.r., and u.v. spectra) with the trimethyl ether (6) obtained by degradation of erythrostominone.[2]

Bromination of 7-Oxo-octanoic Acid.—Bromine was added dropwise to a stirred solution of the oxo-acid (1 g) and potassium chlorate (0.10 g) in water (5 ml) at 60 °C and at such a rate that the colour of the solution was never darker than a light yellow. The addition of bromine was stopped when the solution ceased to become colourless after 10 min. Recovery in chloroform and evaporation *in vacuo* afforded an oil (1.46 g) shown by its n.m.r. spectrum to be a mixture of 70% of 6-bromo-7-oxo-octanoic acid and 30% of 8-bromo-7-oxo-octanoic acid. Crystallisation from chloroform–light petroleum at −20° followed by several recrystallisations from light petroleum afforded *8-bromo-7-oxo-octanoic acid** as needles, m.p. 62—65° (Found: C, 40.15; H, 5.45; Br, 33.95. $C_8H_{13}BrO_3$ requires C, 40.5; H, 5.5; Br, 33.7%).

The mother liquors from the crystallisations were concentrated *in vacuo* to give an oil which was shown (n.m.r. spectrum) to consist of a 9 : 1 mixture of the 6-bromo- and 8-bromo-isomers (Found: C, 40.65; H, 5.7. Calc. for $C_8H_{13}BrO_3$: C, 40.5; H, 5.5%), τ 8.37 (6 H, m, 3-, 4-, and 5-H_2), 7.65 (2 H, m, 2-H_2), 7.64 (3 H, s, 8-H_3), and 5.78 (1 H, t, *J* 7 Hz, 6-H). Its acid chloride, prepared with oxalyl chloride, had b.p. 120—125° at 1 mmHg, $\nu_{max.}$ (film) 1 792 and 1 710 cm^{-1}.

Attempted Dehydrohalogenation of 6-Bromo-7-oxo-octanoic Acid.—(a) *With lithium chloride in dimethylformamide.* The 7 : 3 mixture of 6- and 8-bromo-7-oxo-octanoic acids (1 g) was dissolved in dimethylformamide (4 ml), lithium chloride (0.25 g) was added, and the mixture was heated at 100 °C with stirring under nitrogen for 2 h. It was cooled, ether (25 ml) and 25% sulphuric acid (15 ml) were added, and the resultant mixture was stirred for 16 h. Recovery in ether gave an oil (740 mg) which was a mixture of 6-chloro- and 8-chloro-7-oxo-octanoic acids (Found: C, 50.25; H, 7.05; Cl, 18.4%; *m/e* 192. Calc. for $C_8H_{13}{}^{35}ClO_3$: C, 49.9; H, 6.8; Cl, 18.4%; *M*, 192), $\nu_{max.}$ (film) 3 000, 2 650, and 1 710br cm^{-1}; τ 8.45 (m, 3-, 4-, and 5-H_2), 7.68 (s, 8-H_3 of 6-chloro-acid), 7.65 (m, 2-H_2 of both acids and 6-H_2 of 8-chloro-acid), 5.96 (s, 8-H_2 of 8-chloro-acid), and 5.82br (t, *J* 7.0 Hz, 6-H of 6-chloro-acid).

(b) *With collidine.* A solution of the bromo-acids (90% of 6-bromo-isomer) in collidine (5 ml) was stirred under nitrogen and was heated quickly to 180 °C and refluxed for 15 min. Recovery in chloroform gave an intractable gum.

Dehydrohalogenation of the Ethylene Acetal of 6-Bromo-7-oxo-octanoic Acid.—The 7 : 3 mixture of 6- and 8-bromo-oxo-acids (80 g) and ethylene glycol (150 ml) in benzene (500 ml) were refluxed for 48 h with stirring in the presence of toluene-*p*-sulphonic acid under a Dean–Stark head. Recovery in benzene gave an oil (100 g); its mass spectrum showed that it probably contained the diesters (13)—(15) [*m/e* 575, 573, and 571 (*M* − Me) for *e.g.* (14); *m/e* 495 and 493 (*M* − CH_2Br) for *e.g.* (13)]; its i.r. spectrum [$\nu_{max.}$ (film) 3 500 and 1 730 cm^{-1}] indicated that the monoesters (16) and (17) might also be present.

The acetal mixture (45 g) was stirred with a solution of potassium t-butoxide in dimethyl sulphoxide (400 ml) at 95—105 °C, under nitrogen, for 2 h. The cold solution was poured onto ice (200 g) and neutralised with 2N-sulphuric acid. Recovery by continuous extraction with ether for 61 h and evaporation of the extract *in vacuo* left an oil (14 g) which was combined with the crude product (12 g) from another similar reaction and chromatographed on silica gel (30 × 10 cm). Elution with light petroleum–ethyl acetate (4 : 1) afforded the ethylene acetal of 8-bromo-7-oxo-octanoic acid* as an oil (7.2 g), which crystallised at 0 °C as cubes, m.p. *ca.* 25°.

Hydrolysis of the bromo-acetal (3.3 g) by heating in water (10 ml) and 2N-hydrochloric acid (50 ml) on a steam-bath for 10 min followed by recovery in chloroform gave 8-bromo-7-oxo-octanoic acid, m.p. 62—64°, identical (i.r. and n.m.r. spectra) with the specimen described above.

Further elution of the column with light petroleum–ethyl acetate (7 : 3) gave *7-oxo-oct-5-enoic acid** as an oil (12.44 g) which crystallised at 0° (Found: C, 60.8; H, 8.05%; *m/e* 156.0791. $C_8H_{12}O_3$ requires C, 61.5; H, 7.75%; *M*, 156.0786). Its *dinitrophenylhydrazone* formed orange microcrystals (from ethanol), m.p. 172—173° (Found: C, 50.0; H, 4.8; N, 16.7. $C_{14}H_{16}N_4O_6$ requires C, 50.0; H, 4.8; N, 16.6%). Its acid chloride, prepared with oxalyl chloride, contained 5-chloro-7-oxo-octanoyl chloride. Distillation of the mixture under nitrogen (b.p. 103—106° at 0.8 mmHg) resulted in an increase in the proportion of 7-oxo-oct-5-enoyl chloride.

Treatment of the oxo-octenoic acid with hydrogen chloride in ethanol-free chloroform, followed by reaction with oxalyl chloride, resulted in a mixture of acid chlorides containing >90% of 5-chloro-7-oxo-octanoyl chloride, $\nu_{max.}$ (film) 1 795br and 1 720 cm^{-1}; τ 8.18 (4 H, m, 3- and 4-H_2), 7.83 (3 H, s, 8-H_3), 7.25 (4 H, m, 2- and 6-H_2), and 5.72 (1 H, m, 5-H).

Condensation of 5-Chloro-7-oxo-octanoyl Chloride and

Methyl 3,5-Dimethoxyphenylacetate.—Perchloric acid (70%; 13 drops) was added to a solution of the chloride (5.2 g) (containing <10% of 7-oxo-oct-5-enoyl chloride) and the dimethoxy-ester (1.65 g) in benzene (7.5 ml), which was then stirred under nitrogen for 15 h. Recovery in the usual manner gave an oil which was chromatographed on silica gel (34 × 3.5 cm). Elution with light petroleum–ethyl acetate (9 : 1) gave unchanged ester (800 mg). Elution with light petroleum–ethyl acetate (4 : 1) afforded methyl 2-(5-chloro-1,7-dioxo-octyl)-3,5-dimethoxyphenylacetate (18) as an oil (673 mg) containing a small amount of the unsaturated ketone (19) (Found: *m/e* 384.1342 and 348.1573. Calc. for $C_{19}H_{25}{}^{35}ClO_6$: *M*, 384.1340. Calc. for $C_{19}H_{24}O_6$: *M*, 348.1590), $\nu_{max.}$ 1 740, 1 725, and 1 680 cm^{-1}; τ 8.17 (4 H, m, 3′- and 4′-H_2), 7.82 (3 H, s, 8′-H_3), 7.11 (4 H, m. 2′- and 6′-H_2), 6.36 (2 H, s, ArCH_2·CO), 6.33 (3 H, s, CO_2Me), 6.19 (6 H, s, 2 × OMe), 5.68 (1 H, m, 5′-H), and 3.60 (2 H, s, 4- and 6-H). Weak signals at τ 7.77, 3.90 (d, *J* 16 Hz), and 3.17 (dt, *J* 16 and 6 Hz) were assigned to the unsaturated ketone (19).

Cyclisation of Methyl 2-(5-Chloro-1,7-dioxo-octyl)-3,5-dimethoxyphenylacetate (18).—The chloro-ester (410 mg) was added to a boiling solution of sodium (70 mg) in ethanol (17 ml), which was then refluxed for 20 min, cooled, filtered, aerated for 4 h, and evaporated *in vacuo*. The red oil obtained was divided into two portions; the first was dissolved in water (20 ml) and extracted with chloroform. The aqueous layer was acidified with 2N-hydrochloric acid and was extracted with chloroform. The combined chloroform extracts were evaporated *in vacuo*, and the resultant gum was purified by p.l.c. Development (×3) with chloroform–formic acid (24 : 1) separated a major yellow band, material from which was recovered in acetone and crystallised from ether to give yellow needles (15 mg), m.p. 158—161°, of (±)-2-acetonyl-3,4-dihydro-6,8-dimethoxy-2*H*-naphtho[2,3-*b*]pyran-5,10-quinone (20), identical [t.l.c., i.r. ($CHBr_3$), u.v., n.m.r., and mass spectra] with the methyl derivative of the hydroxy-quinone (21), prepared from erythrostominone (see below).

The other portion of the red oil was dissolved in ice–water (10 ml); the solution was acidified with 2N-hydrochloric acid to pH 2 and extracted with ether. The aqueous layer deposited a green oily solid which was dissolved in N-sodium hydroxide (15 ml); the solution was adjusted with 2N-hydrochloric acid to pH 7, and extracted with ether. Evaporation of the combined ethereal extracts *in vacuo* gave an oil (101 mg) which was purified by p.l.c. Development (×5) with chloroform–formic acid (19 : 1) gave two yellow bands. Material recovered from the front-running band afforded the dimethoxy-quinone (20) described above (5.4 mg). Material from the second band, also recovered in acetone, crystallised from ethanol as yellow plates, m.p. 119—121°, believed to be 2-(3-*ethoxy*-5-*oxohexyl*)-3-*hydroxy*-6,8-*dimethoxy*-1,4-*naphthoquinone* (7) (Found: *m/e* 376.1522. $C_{20}H_{24}O_7$ requires *M*, 376.1537), $\nu_{max.}$ 3 420, 1 715, 1 640, and 1 598 cm^{-1}; $\lambda_{max.}$ 212, 262, 305, 366, and 410sh nm (ε 30 000, 19 380, 10 400, 3 980, and 1 400); τ 8.85 (3 H, t, *J* 7.0 Hz, OCH_2·CH_3), 8.4 (2 H, m, 2′-H), 7.81 (3 H, s, 6′-H_3), 7.74 (2 H, t, *J* 8 Hz, 1′-H_2), 7.37 (2 H, m, 4 lines, 4′-H_2), 6.48 (1 H, m, 3′-H), 6.06 (3 H, s, OMe), 6.04 (3 H, s, OMe), 6.01 (2 H, q, *J* 7.0 Hz, OCH_2·CH_3), 3.25 (1 H, d, *J* 1.5 Hz, 7-H), and 2.74 (1 H, d, *J* 1.5 Hz, 5-H).

Hydrogenation of Erythrostominone (cf. *ref.* 2).—Erythrostominone (200 mg) in glacial acetic acid (22 ml) was hydrogenated over 10% palladium–charcoal (125 mg) for 17 h (uptake *ca.* 5.5 mol. equiv.). Filtration and removal of the solvent *in vacuo* afforded a gum which was purified by p.l.c. Development (×2) with chloroform–methanol (49 : 1) separated three major bands.

Material from the leading band was recovered in acetone and was purified by p.l.c. Development (×10) with benzene–formic acid (49 : 1) separated three orange bands. Recovery of material from the leading band in acetone and crystallisation from ethanol gave orange needles (16 mg), m.p. 167—170° (lit.,[2] 165—168°), identical (t.l.c., i.r. and n.m.r. spectra) with 3,8-dihydroxy-6-methoxy-2-(5-oxohexyl)-1,4-naphthoquinone (9). Material from the second band was recovered in acetone and crystallised from ethanol to give 2-*acetonyl*-3,4-*dihydro*-6-*hydroxy*-8-*methoxy*-2H-*naphtho*[2,3-b]*pyran*-5,10-*quinone* (21), as orange-yellow needles (29 mg), m.p. 146—151° (Found: C, 64.25; H, 5.15%; *m/e* 316. $C_{17}H_{16}O_6$ requires C, 64.55; H, 5.1%; *M*, 316), $\nu_{max.}$ ($CHBr_3$) 1 718, 1 680, and 1 610 cm^{-1}; $\lambda_{max.}$ 215, 264, 312, and 440 nm (ε 24 500, 16 000, 9 100, and 3 160); τ 8.43 (2 H, m, 3-H_2), 7.73 (3 H, s, 3′-H_3), 7.35 (2 H, m, 4-H_2), 7.04 (2 H, 8 lines, 1′-H_2), 6.12 (3 H, s, OMe), 5.42 (1 H, m, 2-H), 3.39 (1 H, d, *J* 1.5 Hz, 7-H), 2.84 (1 H, d, *J* 1.5 Hz, 9-H), and −3.56 (1 H, s, OH). Recovery of material from the third band, followed by crystallisation from ethanol, afforded the isomeric monohydroxy-quinone(s) (22) and/or (23) as orange needles (10 mg), m.p. 175—178° (Found: C, 64.8; H, 5.2%; *m/e* 316. Calc. for $C_{17}H_{16}O_6$: C, 64.55; H, 5.1%; *M*, 316), $\nu_{max.}$ ($CHBr_3$) 1 720, 1 685, 1 630, and 1 596 cm^{-1}; $\lambda_{max.}$ 221, 267, 306, and 430 nm (ε 33 600, 18 950, 9 000, and 4 350); τ 8.44 (2 H, m, 3-H_2), 7.74 (3 H, s, 3′-H_3), 7.21 (4 H, m, 4-H_2 and 1′-H_2), 6.13 (3 H, s, OMe), 5.40 (1 H, m, 2-H), 4.01 (1 H, s, 7-H), 2.91 (1 H, s, 10-H and/or 5-H), and −2.70 (1 H, s, OH).

The second band from p.l.c. of the crude hydrogenation product was recovered in acetone and crystallised from acetone–light petroleum as red rods (7 mg), m.p. 148—150°, identical (i.r. spectrum) with deoxyerythrostominone.

Material recovered from the third band, from the first p.l.c., crystallised from ether as orange crystals (12 mg), m.p. partly 134—137°, remainder at *ca.* 170° of the isomeric trihydroxyquinones (10) and [(24) and/or (25)] (Found: *m/e* 320.1268. Calc. for $C_{17}H_{20}O_6$: *M*, 320.1260), $\nu_{max.}$ ($CHCl_3$ film) 3 520, 3 100br, 1 680, 1 632, and 1 610 cm^{-1}; τ 8.80 (3 H, d, *J* 6 Hz, 6′-H_3), 8.52 (6 H, m, 2′-, 3′-, and 4′-H_2), 7.42 (2 H, m, 1′-H_2), 6.04 (m, 5′-H), 6.02 (3 H, s, OMe), 4.01 and 2.89 (singlets, quinonoid and aromatic H, respectively), 3.35 and 2.82 (doublets, *J* 2 Hz, aromatic protons), and −2.61 (s) and −2.65 (s) (total 1 H, OH).

Methylation of the Hydroxy-quinone (21).—The hydroxy-quinone (9 mg) was stirred in chloroform (2 ml) with methyl iodide (1 ml) and dry silver oxide (100 mg) for 12 h. Evaporation *in vacuo* followed by crystallisation from ethanol gave (+)-2-*acetonyl*-3,4-*dihydro*-6,8-*dimethoxy*-2H-*naphtho*[2,3-b]*pyran*-5,10-*quinone* (20) as needles (7 mg), m.p. 158—160°, $[\alpha]^{22}$ +155° (*c* 0.1) (Found: C, 65.1; H, 5.6%; *m/e* 330. $C_{18}H_{18}O_6$ requires C, 65.4; H, 5.5%; *M*, 330), $\nu_{max.}$ ($CHBr_3$) 1 715, 1 675, and 1 635 cm^{-1}; $\lambda_{max.}$ 214, 262, 305, 370, and 424 nm (ε 24 400, 19 600, 11 200, 3 200, and 2 800); τ 8.31 (2 H, m, 3-H_2), 7.74 (3 H, s, 3′-H_3), 7.38 (2 H, m, 4-H_2), 7.04 (2 H, 8 lines, 1′-H_2), 6.07 (6 H, s, 2 × OMe), 5.47 (1 H, m, 2-H), 3.30 (1 H, d, *J* 2.0 Hz, 7-H), and 2.76 (1 H, d, *J* 2.0 Hz, 9-H).

Hydrolysis of the N-*Methylamide* (26).—The amide (2.5 g) was boiled with a suspension of barium hydroxide (7 g) in

water (100 ml) and the product was isolated as described by Lukeš and Černý;[8] it was an oil, b.p. 70—72° at 8 mmHg, identified as 5-oxohexanoic acid by its n.m.r. spectrum: τ 7.98 (2 H, m, 3-H_2), 7.81 (3 H, s, 6-H_3), 7.58 (2 H, t, *J* 6.5 Hz, 2-H_2), and 7.43 (2 H, t, *J* 6.5 Hz, 4-H_2).

Its semicarbazone crystallised from ethanol as prisms, m.p. 172—173° (lit.,[9] 173—174°) (Found: C, 45.1; H, 6.8; N, 22.45. Calc. for $C_7H_{13}N_3O_3$: C, 44.9; H, 7.0; N, 22.45%), identical (i.r. spectrum) with an authentic specimen.

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