An Investigation into the Formation of Benzo- and Naphtho-pyrans by Cyclisation of *ortho*-Alkenyl(hydroxyalkyl)benzenes using either Cerium(IV) Ammonium Nitrate or Potassium t-Butoxide in Dimethylformamide

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A series of *ortho*-alkenylbenzyl alcohols carrying methoxy substituents at appropriate positions on the aromatic ring have been synthesised. Each of these compounds has been treated separately with each of the title reagents.

The oxidative cyclisation of the naphthalene dimethyl ethers (1) and (2) using cerium(IV) ammonium nitrate (4 mol equiv.) to afford the naphthopyran quinones (3) and (4), and (5) and (6), respectively was recently reported.[1] It was also shown[1] that cyclisation preceded oxidation, by isolating the intermediates (7) and (8) in the conversion of compound (1) into the quinones (3) and (4). While the oxidative demethylation of hydroquinone dimethyl ethers [e.g. (7) and (8)] to quinones [e.g. (3) and (4) respectively] with cerium(IV) ammonium nitrate[2] has become routine and is understood mechanistically, the initial cyclisation of the naphthalene (1) to the naphthopyrans (7) and (8) is novel and required investigation.

We have also shown[3] that the naphthalenes (1) and (2) cyclise rapidly and in high yield to give the naphthopyrans (9) and (11) respectively using potassium t-butoxide in dimethylformamide under anaerobic conditions. In the first case, compound (9) was shown to be the initial product, since longer treatment under the same conditions caused epimerisation to the *cis*-isomer (10).
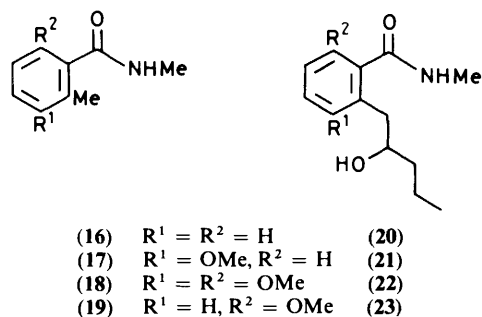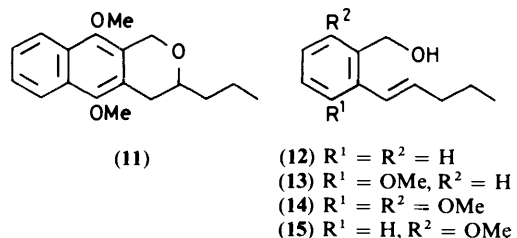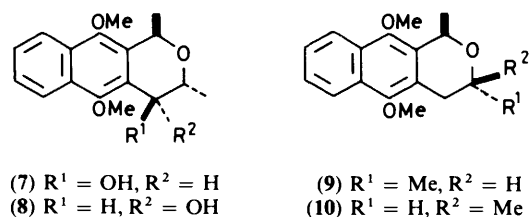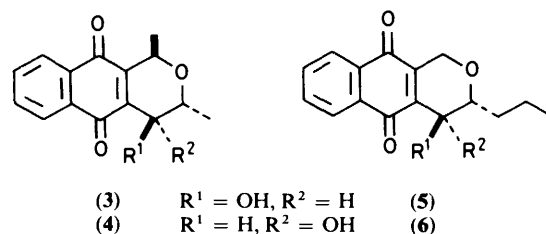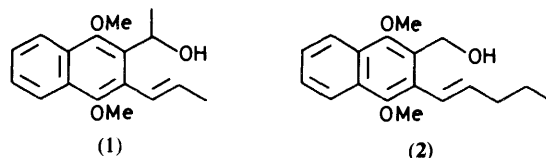
In order to determine which structural features are required in compounds (1) and (2) for each mode of cyclisation, we have made the analogues (12)—(15) of compound (2), each of which lacks one or more of the functionalities present in (2).
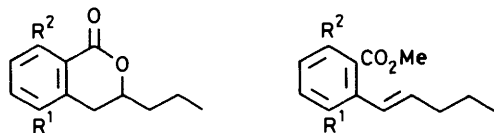
Results and Discussion

In formulating syntheses of compounds (12)—(15), two structural requirements had to be met. First, the alkenyl and hydroxyalkyl substituents were required to be *ortho* to each other, and secondly, it was desirable that the double bond should adopt solely the (*E*)-stereochemistry, as it does in compound (2).

For the synthesis of compound (12), the starting material, *N*-methyl-*o*-toluamide (16), was converted into its dilithio salt with n-butyl-lithium,[4,5] and this was treated with freshly distilled butanal to give the crude hydroxyamide (20). Pyrolysis of this amide afforded the lactone (24) in a yield of 40% from the amide (16). The mass spectrum of the δ-lactone (24) showed the base peak at *m*/*z* 118, consistent with its formulation as a dihydroisocoumarin,[5] which was also evident from the low-field doublet of doublets at δ 8.07 (*J* 2 and 7 Hz) due to 8-H in the ¹H n.m.r. spectrum,[5] and a strong i.r. absorption at 1 710 cm⁻¹. Treatment of the lactone (24) with potassium t-butoxide and dimethyl sulphate in dry dimethylformamide provided a high yield (85%) of the olefinic ester (28), in which the double bond had solely the required (*E*) configuration as evidenced by the large coupling constant (16 Hz) between the olefinic protons in the ¹H n.m.r. spectrum. The ester was reduced to the unsaturated alcohol (12) in high yield with lithium aluminium hydride.

In light of the success achieved in the synthesis of the alcohol (12) from the amide (16), the methoxyamide (17) seemed to be a

(1)

(2)

(3) R¹ = OH, R² = H
(4) R¹ = H, R² = OH

(5)
(6)

(7) R¹ = OH, R² = H
(8) R¹ = H, R² = OH

(9) R¹ = Me, R² = H
(10) R¹ = H, R² = Me

(11)

(12) R¹ = R² = H
(13) R¹ = OMe, R² = H
(14) R¹ = R² = OMe
(15) R¹ = H, R² = OMe

(16) R¹ = R² = H (20)
(17) R¹ = OMe, R² = H (21)
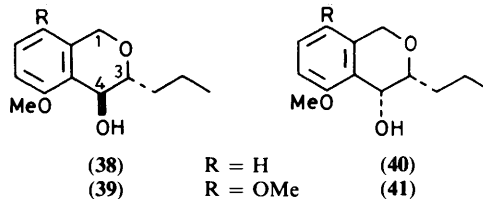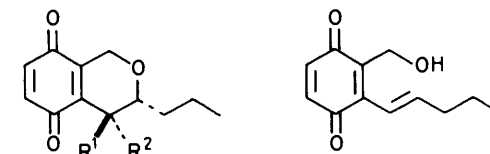(18) R¹ = R² = OMe (22)
(19) R¹ = H, R² = OMe (23)

(24) $R^1 = R^2 = H$ (28)
(25) $R^1 = OMe, R^2 = H$ (29)
(26) $R^1 = R^2 = OMe$ (30)
(27) $R^1 = H, R^2 = OMe$ (31)

(32) $R^1 = OMe, R^2 = H$ (35)
(33) $R^1 = R^2 = OMe$ (36)
(34) $R^1 = H, R^2 = OMe$ (37)

(38) $R = H$ (40)
(39) $R = OMe$ (41)

(42) $R^1 = OH, R^2 = H$ (44)
(43) $R^1 = H, R^2 = OH$

suitable precursor for the alcohol (13). This was conveniently prepared in two very high yielding steps from m-methoxy-N-(t-butyl)benzamide (32), whose dilithio derivative[6] was smoothly methylated with methyl iodide (2 mol equiv.) to give the product (35) of both N- and C-methylation in 93% yield. The t-butyl group of compound (35) was readily removed by stirring at 60 °C in neat trifluoroacetic acid to give the secondary amide (17), a process which could be conveniently monitored kinetically by ^{1}H n.m.r. spectroscopy. The spectrum of the amide (35) in trifluoroacetic acid confirmed the pattern of 1,2,3-trisubstitution with the appearance of three $ortho$-coupled protons in the aromatic region at δ 6.88, 7.08, and 7.26 (each J 7 Hz), This amide was converted via the hydroxyamide (21), the lactone (25), and the unsaturated ester (29) into the alcohol (13).

The alcohol (14) was synthesised using gentisic acid as the starting material; this was converted into its N-t-butylamide (33). Aromatic lithiation of this compound would be expected to take place at the unsubstituted position between the amide and methoxy groups, both by analogy with the lithiation of the amide (32) and also because of the known $ortho$-directing influence of both amide and methoxy groups, the effect of the former being the greater.[7] This was observed in practice, the product being compound (36). This was converted into the alcohol (14) in a series of reactions via the amide (18), the hydroxyamide (22), the lactone (26), and the ester (30). The pattern of 1,2,3,4-tetrasubstitution was confirmed not only by the formation of the lactone (26), but also by the ^{1}H n.m.r. spectrum of (26), in which the $ortho$-coupled protons were observed as a doublet of doublets at δ 6.87 and 7.07 (J 9 Hz).

The possibility of introducting a C-pentyl group directly into the amides (32) and (33) was rejected when it was found that, unlike the methylation reaction, pentylation took place at nitrogen only, when the dilithio salt of the amide (32) was treated with bromopentane. Furthermore, in order to generate the secondary amide (17) and (18) for subsequent dilithiation, the choice of the N-t-butylamides (32) and (33) as starting materials was very useful, as the t-butyl group could be treated as a readily removable protecting group; the alternative use of the N-methylamides (32) and (33) (Me in place of Bu^t) led to the formation of the N,N-dimethylamides related to compounds (35) and (36) (Me in place of Bu^t), from which the secondary amides (17) and (18) could not readily be obtained.

Oxidation of the alcohol (12) with cerium(IV) ammonium nitrate (2 mol equiv.) afforded a complex reaction mixture from which no product was characterised. However, the similar reaction of the methoxy analogue (13) gave two products which were identified as the hydroxyisochromans (38) (18%) and (40) (48%). The stereochemical assignments were made on the basis

of the ^{1}H n.m.r. spectra of the compounds. The minor isomer (38), which had the higher R_F value,[1] showed the four pyran ring protons as a three-proton signal at δ 4.71 consisting of a singlet due to the two methylene protons at C-1 superimposed on a broadened doublet due to the pseudoaxial proton 4-H, and a further one proton signal at δ 3.58 due to the axial proton 3-H, which was partially obscured by the resonance of the hydroxy group. Exchange of the hydroxy proton with deuterium oxide simplified the latter signal to a doublet of triplets (J 8 and 2.5 Hz). Simultaneous double irradiation of the propyl methylene protons vicinal to 3-H at δ 1.67 collapsed 3-H to a doublet (J 8 Hz), this remaining coupling being with the neighbouring proton 4-H. The magnitude of the coupling constant indicated that 3-H was axial and 4-H pseudoaxial, from which it followed that the C-3 propyl was equatorial and the C-4 hydroxy pseudoequatorial. Related arguments led to the assignment of structure (40) to the major isomer, in which the coupling constant between 3-H and 4-H was of the order of 2 Hz; it followed from this that the C-4 hydroxy group was pseudoaxial. The predominance of the pseudoaxial hydroxy epimer was in agreement with the preponderance of the pseudoaxial products (4), (6), and (8) in the formation of the epimeric pairs (3) and (4), (5) and (6), and (7) and (8), and a reason has been put forward for this.[1]

Treatment of the dimethoxybenzyl alcohol (14) with cerium(IV) ammonium nitrate (2 mol equiv.) similarly afforded the pair of epimeric hydroxyisochromans (39) (21%) and (41) (30%), whose relative stereochemistries once again followed from their ^{1}H n.m.r. spectra. The combined yield was somewhat less than that for the oxidation of the monomethoxy compound (13), and this was ascribed to the greater complexity of the reaction, since further oxidation of the products (39) and (41) to the corresponding quinones (42) and (43) was taking place to a minor degree, as was the oxidative demethylation of the hydroquinone dimethyl ether (14) to the olefinic quinone (44). The latter was identified as having the same R_F as the material obtained by the silver(II) oxide oxidation of compound (14);[1] the quinone (44) was somewhat unstable and was not fully characterised.

Oxidation of the dimethoxybenzyl alcohol (14) with cerium(IV) ammonium nitrate (4 mol equiv.) gave rise to a mixture containing the quinones (42) and (43) directly. Column chromatography afforded the pure pseudoaxial hydroxy compound (43), but the pseudoequatorial epimer (42) was contaminated with the olefinic quinone (44) and it was difficult to separate these. The pseudoequatorial hydroxy quinone (42) was best prepared by silver(II) oxide oxidation of the hydroquinone dimethyl ether (39), and the epimeric quinone was similarly prepared from compound (41).

(45) R = OMe
(46) R = H

(47)

Scheme.
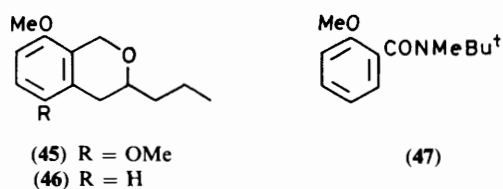
Attention was then focused on the cyclisation of compounds (1) and (2) to give the products (9) and (11) respectively in the presence of potassium t-butoxide in dry dimethylformamide under nitrogen. The benzyl alcohols (12) and (13), when treated under the same conditions, were recovered unchanged, and prolonging the reaction time made no difference. In stark contrast, the alcohol (14) carrying two methoxy groups cyclised readily to compound (45) in a yield of 85%. In order to see whether the methoxy group *ortho* to the hydroxymethyl was effective by itself in promoting cyclisation, the 2-methoxy-6-pentenylbenzyl alcohol (15) was prepared. Treatment of compound (15) with butoxide in dimethylformamide gave a number of products, but the major component (25%) was the cyclic ether (46). Thus, cyclisation does occur in this case, although the yield is much lower.

The alcohol (15) was synthesised from the amide (19) *via* the sequence (19)→(23)→(27)→(31)→(15) in the manner described above for the related compounds. The initial route investigated to the amide (19) involved the dilithiation of *o*-methoxy-*N*-t-butylbenzamide in which aromatic lithiation would be expected to occur adjacent to the amide function rather than the methoxy group in view of the stronger *ortho*-directing influence of the former.[7,*] However, lower yields might be expected than those obtained in the case of the isomeric compound (17), where the directive effects were complementary, and this turned out to be the case of practice. While subsequent aromatic methylation of the dilithio derivative of compound (34) gave the 2,6-disubstituted amide (37) exclusively, this product was contaminated by considerable quantities of the amide (47) and it was difficult to separate these chromatographically. An alternative and convenient method well suited to large scale preparation was therefore used in which the known[8] 2-methoxy-6-methylbenzoic acid was converted by standard methods into the amide (19).

Treatment of the alcohol (15) with cerium(IV) ammonium nitrate (2 mol equiv.) gave a mixture of products, none of which was identified as a hydroxyisochroman.

This result indicates that in the cerium-promoted oxidative cyclisation of compounds (1) and (2), the methoxy *ortho* to the alkenyl group plays a key role. A mechanism consistent with the experimental observations is outlined in the Scheme. A resonance-stabilised radical cation (49↔50↔51) is formed by oxidation of (1) at the methoxy *ortho* to the alkenyl substituent with cerium(IV) (1 mol equiv.). Ring-closure and loss of a proton give rise to a benzylic radical (52) which undergoes oxidation with a second cerium ion to give the benzylic carbonium ion (53); this then undergoes nucleophilic attack by the water present to give the products (7) and (8). Other evidence consistent with the formation of a carbonium ion intermediate has already been put forward.[1]

As far as the base cyclisations are concerned, the results in summary are that the alcohols (1), (2) and (14) cyclise readily, while the alcohols (12) and (13) do not cyclise at all, and alcohol
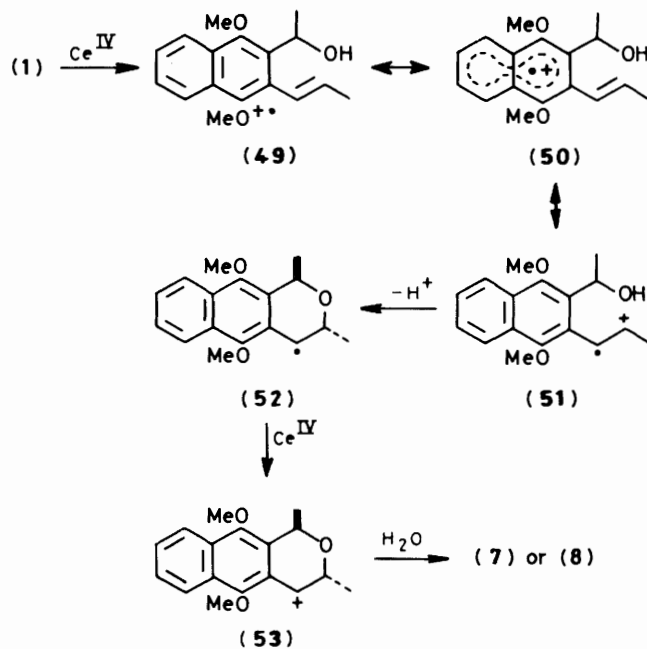
(15), isomeric with (13) undergoes cyclisation in low yield. The explanation for this unusual reaction may involve steric effects, since it is those alcohols in which both the hydroxymethyl and alkenyl substituents are flanked by methoxy groups (forcing the reacting centres into close proximity) that cyclise readily and in high yield. A literature precedent does exist[9] for the formation of ethers, under basic conditions, from the reaction of an alcohol function with an unactivated double bond when the two are held in close proximity. However, further work will have to be done to exclude the involvement of electronic factors.

Experimental

Unless otherwise stated i.r. spectra were measured for Nujol mulls and n.m.r. spectra for solutions in deuteriochloroform with tetramethylsilane as internal reference. Column chromatography was carried out on dry columns with Merck Kieselgel 60 (70—230 mesh) as adsorbent. Preparative layer chromatography (p.l.c.) was performed on glass plates coated with Merck Kieselgel 60F$_{254}$. Light petroleum refers to the fraction of b.p. 60—80 °C, and ether to diethyl ether. The phrase 'residue obtained upon work-up' refers to the residue when the organic layer was separated, dried (MgSO$_4$), and the solvent evaporated under reduced pressure.

General Method for the Synthesis of the Lactones (24)—(27) *from the Toluamides* (16)—(19).—The amide was dissolved in dry tetrahydrofuran and the reaction flask was flushed with nitrogen. n-Butyl-lithium (2.5 mol equiv.) in hexane was added at room temperature, and the red solution was boiled for 15 min. The flask was then cooled in ice, and butanal (2 mol equiv.) was added during 30 min. The reaction mixture was stirred at room temperature for 45 min, and was then poured into hydrochloric acid (2M) containing half its mass of ice. This was extracted with ethyl acetate. The residue obtained upon work-up was heated at 200—215 °C until the evolution of methylamine was no longer detected (normally about 5 h). The resulting oil was chromatographed.

*3,4-Dihydro-3-propyl-*1H-*2-benzopyran-1-one* (24). *N*-Methyl-*o*-toluamide (3.70 g, 25 mmol) in tetrahydrofuran (60 ml) was

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* For a related case of the *ortho*-lithiation of the tertiary amide *N*,*N*-dimethyl-*o*-methoxybenzamide with s-butyl-lithium–tetramethylenediamine, see M. Watanaba, M. Sahara, S. Furukawa, R. Billedeau, and V. Snieckus, *Tetrahedron Lett.*, 1982, 1647.

treated as described above, and then chromatographed (eluant 5% ethyl acetate–light petroleum) to give the *product* (24) (1.75 g, 40%) as an oil (Found: C, 75.6; H, 7.45. $C_{12}H_{14}O_2$ requires C, 75.75; H, 7.4%), $v_{max.}$(film) 1 710 cm^{-1} (C=O); δ 0.98 (3 H, t, *J* 6 Hz, CH$_3$), 1.2—2.0 (4 H, m, CH$_2$CH$_2$), 2.93 (2 H, apparent d, *J* 6.5 Hz, ArCH$_2$), 4.35—4.70 (1 H, m, 3-H), 7.15—7.7 (3 H, m, 5-, 6-, and 7-H), and 8.07 (1 H, dd, *J* 2 and 7 Hz, 8-H); *m/z* 190 (M^+, 17%), 147 (76), 119 (88), 118 (100), 91 (50), and 90 (61).

3,4-*Dihydro-5-methoxy-3-propyl*-1H-2-*benzopyran*-1-*one* (25). The amide (17) (2.89 g, 16 mmol) in tetrahydrofuran (20 ml) was treated as above, and then chromatographed (eluant 15% ethyl acetate–light petroleum) to afford the *product* (25) (1.89 g, 53%) as an oil (Found: C, 70.8; H, 7.6. $C_{13}H_{16}O_3$ requires C, 70.9; H, 7.3%); $v_{max.}$(film) 1 718 cm^{-1} (C=O); δ 0.97 (3 H, t, *J* 6.5 Hz, CH$_3$), 1.3—2.0 (4 H, m, CH$_2$CH$_2$), 2.64 (1 H, dd, *J* 12 and 17 Hz, pseudoaxial 4-H), 3.15 (1 H, dd, *J* 4 and 17 Hz, pseudoequatorial 4-H), 3.88 (3 H, s, OCH$_3$), 4.3—4.65 (1 H, m, 3-H), 7.07 (1 H, d, *J* 8 Hz, 6-H), 7.33 (1 H, t, *J* 8 Hz, 7-H), and 7.71 (1 H, d, *J* 8 Hz, 8-H); *m/z* 220 (M^+, 58%) 177 (32), 149 (89), 148 (100), 120 (34), 91 (33), and 90 (26).

3,4-*Dihydro-5,8-dimethoxy-3-propyl*-1H-2-*benzopyran*-1-*one* (26). The amide (18) (5.00 g, 23.9 mmol) in tetrahydrofuran (300 ml) was treated as above. After being heated for 4 h, the residue was chromatographed (eluant 50% ethyl acetate–light petroleum) to afford the *product* (26) [1.69 g, 28%, or 49% based on unrecovered (18) and (22)], m.p. 55.5—56 °C (Found: C, 66.9; H, 7.3. $C_{14}H_{18}O_4$ requires C, 67.2; H, 7.2%); $v_{max.}$ 1 732 and 1 722 cm^{-1} (C=O); δ 0.95 (3 H, t, *J* 7 Hz, CH$_3$), 1.3—2.0 (4 H, m, CH$_2$CH$_2$), 2.54 (1 H, dd, *J* 12 and 17 Hz, pseudoaxial 4-H), 3.14 (1 H, dd, *J* 3 and 17 Hz, pseudoequatorial 4-H), 3.82 and 3.89 (3 H, each, s, OCH$_3$), 4.2—4.5 (1 H, m, 3-H), and 6.87 and 7.07 (2 H, dd, *J* 9 Hz, 6- and 7-H); *m/z* 250 (M^+, 28%), 207 (100), 179 (22), and 150 (28). Later fractions afforded the amide (18) (1.33 g, 27%) followed by the intermediate hydroxyamide (22) (1.05 g, 16%).

3,4-*Dihydro-8-methoxy-3-propyl*-1H-2-*benzopyran*-1-*one* (27). The amide (19) (1.92 g, 10.7 mmol) in tetrahydrofuran (70 ml) was treated as above. After being heated for 16 h, the residue was chromatographed (eluant 20% ethyl acetate–light petroleum) to give rise to the *product* (27) (0.64 g, 27%, or 31% based on unrecovered starting material) as an oil (Found: C, 70.9; H, 7.35. $C_{13}H_{16}O_3$ reqires C, 70.9; H, 7.3%); $v_{max.}$(film) 1 720 cm^{-1} (C=O); δ 0.96 (3 H, t, *J* 7 Hz, CH$_3$), 1.2—2.0 (4 H, m, CH$_2$CH$_2$), 2.8—3.0 (2 H, m, ArCH$_2$), 3.95 (3 H, s, OCH$_3$), 4.4 (1 H, m, 3-H), 6.82 and 6.96 (1 H each, d, *J* 8.5 Hz, 5- and 7-H), and 7.47 (1 H, t, *J* 8.5 Hz, 6-H); *m/z* 220 (M^+, 57%), 149 (100), 148 (84), 146 (38), 91 (45), and 90 (43).

General Method for the Synthesis of the Olefinic Esters (28)—(31) *from the Lactones* (24)—(27).—The lactone was dissolved in dry dimethylformamide, and potassium-t-butoxide (4 mol equiv.) was added. The solution was maintained at 90 °C for 0.5 h, and dimethyl sulphate (4 mol equiv.) was added. The solution was stirred for a further 3 h. After cooling, the mixture was thrown into water, and then extracted exhaustively with ether. The ether layer was washed successively with aqueous ammonia (25%), water, dilute hydrochloric acid, and then more water. The residue obtained upon work-up was chromatographed.

(E)-*Methyl 2-pent-1-enylbenzoate* (28). The lactone (24) (1.15 g, 6 mmol) in dimethylformamide (25 ml) was treated as above. Chromatography (eluant 2.5% ethyl acetate–light petroleum) afforded the *product* (28) (0.81 g, 65%, or 85% based on unrecovered starting material) as an oil (Found: C, 76.2; H, 8.05. $C_{13}H_{16}O_2$ requires C, 76.45; H, 7.9%); $v_{max.}$(film) 1 712 cm^{-1} (C=O); δ 0.96 (3 H, t, *J* 7 Hz, CH$_3$), 1.54 (2 H, sextet, *J* 7 Hz, 4-CH$_2$), 2.06 (2 H, q, *J* 7 Hz, 3-CH$_2$), 3.89 (3 H, s, OCH$_3$), 6.14 (1 H, dt, *J* 7 and 16 Hz, 2-CH), 7.14 (1 H, d, *J* 16 Hz, 1-CH), 7.1—

7.65 (3 H, m, 3-, 4-, and 5-H), and 7.84 (1 H, dd, *J* 1.5 and 8 Hz, 6-H); *m/z* 204 (M^+, 68%), 172 (38), 161 (100), 157 (58), 144 (74), 115 (78), and 91 (46).

(E)-*Methyl 3-methoxy-2-pent-1-enylbenzoate* (29). The lactone (25) (530 mg, 2.4 mmol) in dimethylformamide (35 ml) when treated as above afforded, upon chromatography (eluant 5% ethyl acetate–light petroleum) the oily *ester* (29) (300 mg, 53%, yield not optimised) (Found: C, 72.05; H, 7.75. $C_{14}H_{18}O_3$ requires C, 71.85; H, 7.7%); $v_{max.}$(film) 1 722 cm^{-1}; δ 0.96 (3 H, t, *J* 7 Hz, CH$_3$), 1.50 (2 H, sextet, *J* 7 Hz, 4-CH$_2$), 2.21 (2 H, q, *J* 7 Hz, 3-CH$_2$), 3.84 (6 H, s, OCH$_3$), 6.00 (1 H, dt, *J* 7, and 16 Hz, 2-CH), 6.62 (1 H, d, *J* 16 Hz, 1-CH), 6.9—7.1 (1 H, m, 4-H), and 7.15—7.30 (2 H, m, 5- and 6-H); *m/z* 234 (M^+, 100%), 202 (72), 191 (87), 179 (99), and 173 (71).

(E)-*Methyl 3,6-dimethoxy-2-pent-1-enylbenzoate* (30). The lactone (26) (1.67 g, 6.7 mmol) in dimethylformamide (60 ml) was treated as above and then chromatographed (30% ethyl acetate–light petroleum) to give the *product* (30) (1.34 g, 76%, or 81% based on unrecovered starting material) (Found: C, 68.25; H, 7.65. $C_{15}H_{20}O_4$ requires C, 68.2; H, 7.6%); $v_{max.}$(film) 1 728 cm^{-1} (C=O); δ 0.94 (3 H, t, *J* 7 Hz, CH$_3$), 1.47 (2 H, sextet, *J* 7 Hz, 4-CH$_2$), 2.17 (2 H, q, *J* 7 Hz, 3-CH$_2$), 3.78 (6 H, s, OCH$_3$), 3.96 (3 H, s, OCH$_3$), 6.10 (1 H, dt, *J* 7 and 16 Hz, 2-CH), 6.42 (1 H, d, *J* 16 Hz, 1-CH), and 6.70 and 6.84 (1 H each, *J* 9 Hz, 4- and 5-H); *m/z* 264 (M^+, 100%), 233 (33), 221 (33), and 203 (75).

(E)-*Methyl 6-methoxy-2-pent-1-enylbenzoate* (31). The lactone (27) (102 mg, 4.6 mmol) in dimethylformamide (20 ml) was treated as above and then chromatographed (eluant 30% ethyl acetate–light petroleum) to give the oily *ester* (31) (76 mg, 70%) (Found: C, 71.7; H, 7.9. $C_{14}H_{18}O_3$ requires C, 71.85; H, 7.7%); $v_{max.}$(film) 1 730 cm^{-1}; δ 0.94 (3 H, t, *J* 7 Hz, CH$_3$), 1.45 (2 H, sextet, *J* 7 Hz, 4-CH$_2$), 1.8—2.3 (2 H, m, 3-CH$_2$), 3.71 and 3.79 (3 H, each, s, OCH$_3$), and 6.0—7.3 (5 H, m, 1- and 2-CH, and 3-, 4-, and 5-H); *m/z* 234 (M^+, 100%) 191 (86), and 174 (98).

General Method for the Synthesis of the Benzyl Alcohols (12)—(15).—The ester dissolved in dry ether was added dropwise to a suspension of lithium aluminium hydride (2 mol equiv.) in dry ether at room temperature. After the mixture had been stirred for 0.5 h, sufficient saturated aqueous ammonium chloride was added to decompose the excess of reagent, followed by anhydrous MgSO$_4$. After filtration, the solvent was removed to give the alcohol.

(E)-2-*Pent-1-enylbenzyl alcohol* (12). The ester (28) (0.81 g, 3.95 mmol) in ether (25 ml) afforded a residue which was chromatographed (eluant 10% ethyl acetate–light petroleum) to give the *product* (12) (0.56 g, 81%) as an oil (Found: C, 81.9; H, 9.3. $C_{12}H_{16}O$ requires C, 81.75; H, 9.15%); $v_{max.}$(film) 3 310 cm^{-1} (OH); δ 0.96 (3 H, t, *J* 7 Hz, CH$_3$), 1.52 (2 H, sextet, *J* 7 Hz, 4-CH$_2$), 1.80 (1 H, br s, OH), 2.23 (2 H, q, *J* 7 Hz, 3-CH$_2$), 4.71 (2 H, s, ArCH$_2$), 6.14 (1 H, dt, *J* 7 and 16 Hz, 2-CH), 6.70 (1 H, d, *J* 16 Hz, 1-CH), and 7.1—7.6 (4 H, m, ArH).

(E)-3-*Methoxy-2-pent-1-enylbenzyl alcohol* (13). The ester (29) (234 mg, 1.00 mol) in dry ether (20 ml) afforded, after chromatography (eluant 15% ethyl acetate–light petroleum) the oily *product* (13) (197 mg, 95%) (Found: C, 75.55; H, 8.65. $C_{13}H_{18}O_2$ requires C, 75.7; H, 8.7%); $v_{max.}$(film) 3 220 cm^{-1} (OH); δ 0.97 (3 H, t, *J* 7 Hz, CH$_3$), 1.43 (2 H, sextet, *J* 7 Hz, 4-CH$_2$), 1.97 (1 H, br s, OH), 2.25 (2 H, q, *J* 7 Hz, 3-CH$_2$), 3.81 (3 H, s, OCH$_3$), 4.70 (2 H, s, ArCH$_2$), 6.06 (1 H, dt, *J* 7 and 16 Hz, 2-CH), 6.43 (1 H, d, *J* 16 Hz, 1-CH), 6.83 and 7.03 (each 1 H, dd, *J* 1.5 and 8 Hz, 4- and 6-H), and 7.20 (1 H, t, *J* 8 Hz, 5-H); *m/z* 206 (M^+, 65%), 159 (100), 135 (35), and 91 (42).

(E)-3,6-*Dimethoxy-2-pent-1-enylbenzyl alcohol* (14). The ester (30) (1.06 g, 4.01 mmol) in dry ether (50 ml) afforded, after work-up and chromatography (eluant 30% ethyl acetate–light petroleum), the *product* (14) (0.76 g, 80%), as an oil (Found: C, 70.9; H, 8.55. $C_{14}H_{20}O_3$ requires C, 71.2; H, 8.5%); $v_{max.}$ 3 415

cm^{-1} (OH); δ 0.97 (3 H, t, J 7 Hz, CH$_3$), 1.54 (2 H, sextet, J 7 Hz, 4-CH$_2$), 2.26 (2 H, q, J 7 Hz, 3-CH$_2$), 2.50 (1 H, t, J 6 Hz, OH), 3.78 and 3.84 (each 3 H, s, OCH$_3$), 4.78 (2 H, d, J 6 Hz, ArCH$_2$), 5.95 (1 H, dt, J 7 and 17 Hz, 2-CH), 6.49 (1 H, d, J 17 Hz, 1-CH), and 6.75 (2 H, s, 4- and 5-H); m/z 236 (M^+, 98%), 189 (100), and 165 (52).

(E)-6-*Methoxy*-2-*pent*-1-*enylbenzyl alcohol* (15). The ester (31) (0.46 g, 1.97 mmol) in dry ether (30 ml) similarly afforded after chromatography (eluant 30% ethyl acetate–light petroleum) the oily *alcohol* (15) (0.38 g, 94%) (Found: C, 75.55; H, 8.8. C$_{13}$H$_{18}$O$_2$ requires C, 75.7; H, 8.7%); $v_{max.}$ 3 420 cm^{-1} (OH); δ 0.98 (3 H, t, J 7 Hz, CH$_3$), 1.50 (2 H, m, J 7 Hz, 4-CH$_2$), 2.25 (2 H, q, J 7 Hz, 3-CH$_2$), 1.8—2.4 (1 H, br s, OH), 3.90 (3 H, s, OCH$_3$), 4.88 (2 H, s, ArCH$_2$), 6.21 (1 H, dt, J 7 and 16 Hz, 2-CH), and 6.7—7.5 (4 H, m, ArH and 1-CH); m/z 206 (M^+, 48%), 173 (46), 163 (62), 159 (100), 149 (50), 135 (45), and 91 (59).

2,5-*Dimethoxy*-N-(*t-butyl*)*benzamide* (33).—2,5-Dimethoxy-benzoic acid (18.50 g, 102 mmol) was dissolved in thionyl chloride (60 ml) and boiled for 3 h. The solvent was evaporated off and the residue was added to a solution of sodium hydroxide (5 g) and t-butylamine (20 ml, 190 mmol) in water (100 ml). The mixture was shaken vigorously and then cooled in ice for 1 h. The organic material was extracted into ether and the residue obtained upon work-up was chromatographed (eluant 50% ethyl acetate–light petroleum) to afford the *amide* (33) (18.86 g, 78%), as white rods, m.p. 64—65 °C (light petroleum) (Found: C, 65.9; H, 8.1; N, 5.9. C$_{13}$H$_{19}$NO$_3$ requires C, 65.8; H, 8.0; N, 5.9%); $v_{max.}$ 3 380 (NH), 1 655 cm^{-1} (C=O); δ 1.48 (9 H, s, CCH$_3$), 3.82 and 3.90 (each 3 H, s, OCH$_3$), 6.8—7.1 (2 H, m, 4- and 5-H), 7.66 (1 H, d, J 3 Hz, 2-H), and 7.98 (1 H, br s, NH); m/z 237 (M^+, 75%), 181 (24), 165 (100), 163 (33), and 136 (29).

2-*Methoxy*-N-(*t-butyl*)*benzamide* (34).—2-Methoxybenzoic acid (24.5 g, 161 mmol) when treated as above gave after chromatography (25% ethyl acetate–light petroleum) the *product* (34) (25.1 g, 75%), m.p. 31—33 °C (Found: C, 69.55; H, 8.3; N, 6.95. C$_{12}$H$_{17}$NO$_2$ requires C, 69.6; H, 8.2; N, 6.8%); $v_{max.}$ 3 380 (NH), 1 662 cm^{-1} (C=O); δ 1.47 (9 H, s, CCH$_3$), 3.92 (3 H, s, OCH$_3$) 6.94 (1 H, d, J 8 Hz, 3-H), 7.05 (1 H, t, J 8 Hz, 5-H), 7.40 (1 H, dt, J 2 and 8 Hz, 4-H), 7.84 (1 H, br s, NH), and 8.19 (1 H, dd, J 2 and 8 Hz, 6-H); m/z 207 (M^+, 46%), 192 (23), and 135 (100).

General Method for the Methylation of the Amides (32)—(34).—The amide was dissolved in dry tetrahydrofuran and cooled to -78 °C. n-Butyl-lithium (2.5 mol equiv.) in hexane was added dropwise, the reaction being performed under nitrogen. The solution was stirred for 20 min, warmed to -10 °C, and stirred for a further 30 min. Methyl iodide (3 mol equiv.) was then added and the solution was stirred at this temperature for 1 h and then at room temperature for a further 1 h. The mixture was added to water, and the residue obtained upon work-up was chromatographed to afford the product.

3-*Methoxy*-2,N-*dimethyl*-N-(*t-butyl*)*benzamide* (35). The amide (32) (100 mg, 0.48 mmol) in tetrahydrofuran (30 ml) was treated as above, then chromatographed (eluant 15% ethyl acetate–light petroleum) to give the *product* (35) (106 mg, 93%), m.p. 106—108 °C (aqueous ethanol) (Found: C, 71.55; H, 8.95; N, 6.0. C$_{14}$H$_{21}$NO$_2$ requires C, 71.5; H, 8.9; N, 6.0%); $v_{max.}$ 1 620 cm^{-1} (C=O); δ 1.53 (9 H, s, CCH$_3$), 2.15 (3 H, s, ArCH$_3$), 2.63 (3 H, s, NCH$_3$), 3.80 (3 H, s, OCH$_3$), 6.64 and 6.77 (each 1 H, d, J 8 Hz, 4- and 6-H), and 7.16 (1 H, t, J 8 Hz, 5-H); m/z 235 (M^+, 45%), 220 (18), 179 (24), 150 (30), 149 (100), 148 (37), and 91 (46).

3,6-*Dimethoxy*-2,N-*dimethyl*-N-(*t-butyl*)*benzamide* (36). The amide (33) (21.5 g, 91 mmol) in tetrahydrofuran (250 ml) was treated as above and then chromatographed (eluant 15% ethyl acetate–light petroleum) to give the *product* (36) (22.36 g, 93%),

m.p. 102—103 °C (light petroleum) (Found: C, 67.8; H, 8.65; N, 5.2. C$_{15}$H$_{23}$NO$_3$ requires C, 67.9; H, 8.7; N, 5.3%); $v_{max.}$ 1 642 cm^{-1} (C=O); δ 1.56 (9 H, s, CCH$_3$), 2.12 (3 H, s, ArCH$_3$), 2.74 (3 H, s, NCH$_3$), 3.76 and 3.78 (each 3 H, s, OCH$_3$), and 6.69 (2 H, s, ArH); m/z 265 (M^+, 65%), 209 (22), 180, (32), 179 (100), and 178 (21).

2-*Methoxy*-6,N-*dimethyl*-N-(*t-butyl*)*benzamide* (37). The amide (34) (0.50 g, 2.4 mmol) in tetrahydrofuran (60 ml) was treated as above and then chromatographed (eluant 15% ethyl acetate–light petroleum) to give the *product* (37) (0.37 g, 65%), m.p. 73.5—74.5 °C (light petroleum) (Found: C, 71.75; H, 9.2; N, 6.1. C$_{14}$H$_{21}$NO$_2$ requires C, 71.5; H, 8.9; N, 6.0%); $v_{max.}$ 1 642 and 1 632 cm^{-1} (C=O); δ 1.55 (9 H, s, CCH$_3$), 2.23 (3 H, s, ArCH$_3$), 2.74 (3 H, s, NCH$_3$), 3.77 (3 H, s, OCH$_3$), 6.70 and 6.77 (each 1 H, d, J 8 Hz, 3- and 5-H), and 7.15 (1 H, t, J 8 Hz, 4-H); m/z 235 (M^+, 19%) and 149 (100).

The yield of the amide (37) was variable and it was often, chromatographically, closely followed by the amide (47), δ 1.53 (9 H, s, CCH$_3$), 2.78 (3 H, s, NCH$_3$), 3.83 (3 H, s, OCH$_3$), and 6.65—7.4 (4 H, m, ArH). In addition early fractions gave variable yields of 2-methoxyvalerophenone, δ 0.92 (3 H, t, J 6 Hz, CCH$_3$), 1.2—1.9 (4 H, m, 3- and 4-CH$_2$), 2.97 (2 H, t, J 6 Hz, COCH$_2$), 3.89 (3 H, s, OCH$_3$), 6.96 and 7.04 (each 1 H, d, J 8 Hz, 3-and 5-H), 7.46 (1 H, dt, J 2 and 8 Hz, 4-H), and 7.66 (1 H, dd, J, 2 and 8 Hz, 6-H); m/z 192 (2%), 150 (20), and 135 (100).

General Method for the Synthesis of the Toluamides (17)—(19) *from the Amides* (35)—(37).—The amide was dissolved in trifluoroacetic acid and the solution was maintained at 60 °C. When t.l.c. showed that no more starting material was present (generally about 18 h) the solvent was evaporated off and the residue was chromatographed.

3-*Methoxy*-2,N-*dimethylbenzamide* (17). The amide (35) (995 mg, 4.23 mmol) was treated as above and then chromatographed (eluant 50% ethyl acetate–light petroleum) to give firstly starting material (103 mg, 10%) followed by the *product* (17) (656 mg, 87%, or 97% based on unrecovered starting material), m.p. 109—110 °C (ethanol–water 5:95) (Found: C, 66.7; H, 7.2; N, 7.85. C$_{10}$H$_{13}$NO$_2$ requires C, 67.0; H, 7.3; N, 7.8%); $v_{max.}$ 3 270 (NH) and 1 637 cm^{-1} (C=O); δ 2.25 (3 H, s, CCH$_3$), 3.95 (3 H, d, J 5 Hz, NCH$_3$), 3.84 (3 H, s, OCH$_3$), 5.90 (1 H, br s, NH), 6.86 and 6.90 (each 1 H, d, J 8 Hz, 4- and 6-H), and 7.16 (1 H, t, J 8 Hz, 5-H); m/z 179 (M^+, 71%), 164 (9), 149 (100), 148 (20), and 91 (54).

3,6-*Dimethoxy*-2,N-*dimethylbenzamide* (18). The amide (36) (10 g, 37.7 mmol) was treated as above, then chromatographed (eluant 70% ethyl acetate–light petroleum) to give the *product* (18) (6.97 g, 88%), m.p. 170—171 °C (ethanol) (Found: C, 63.05; H, 7.1; N, 6.7. C$_{11}$H$_{15}$NO$_3$ requires C, 63.1; H, 7.2; N, 6.7%); $v_{max.}$ 3 300 (NH), 1 640, and 1 623 cm^{-1} (C=O); δ 2.07 (3 H, s, CCH$_3$), 2.98 (3 H, d, J 5 Hz, NCH$_3$), 3.76 and 3.78 (each 3 H, s, OCH$_3$), 5.8 (1 H, br s, NH), and 6.66 and 6.78 (each 1 H, d, J 9 Hz, 4- and 5-H); m/z 209 (M^+, 74%), and 179 (100).

2-*Methoxy*-6,N-*dimethylbenzamide* (19). (*a*) The amide (37) (220 mg, 0.94 mmol) was treated as above and then chromatographed (eluant 50% ethyl acetate–light petroleum) to afford the *product* (19) (154 mg, 92%), m.p. 165—166.5 °C (aqueous ethanol) (Found: C, 66.75; H, 7.25; N, 8.0. C$_{10}$H$_{13}$NO$_2$ requires C, 67.0; H, 7.3; N, 7.8%); $v_{max.}$ 3 260 (NH) and 1 635 cm^{-1} (C=O); δ 2.34 (3 H, s, CCH$_3$), 2.99 (3 H, d, J 5 Hz, NCH$_3$), 3.85 (3 H, s, OCH$_3$), 6.32 (1 H, br s, NH), 6.89 and 6.98 (each 1 H, d, J 8 Hz, 3-and 5-H), and 7.37 (1 H, t, J 8 Hz, 4-H); m/z 179 (M^+, 36%), 149 (100), and 91 (22).

(*b*) 2-Methoxy-6-methylbenzoic acid (14.10 g, 84.9 mmol) was boiled in thionyl chloride (70 ml) under nitrogen for 4 h. The excess of thionyl chloride was removed by evaporation, and the residue was added to an ice-cooled solution of methylamine in water (40%; 50 ml) with stirring, whereupon crystals separated.

After 1 h, the mixture was extracted with ether and the residue obtained upon work-up was chromatographed as above to give rise to the product (**19**) (10.5 g, 68%), identical with the material described in (*a*) above.

(3R,4S)-3,4-*Dihydro*-4-*hydroxy*-5-*methoxy*-3-*propyl*-1H-2-*benzopyran* (**38**) *and* (3R,4R)-3,4-*Dihydro*-4-*hydroxy*-5-*methoxy*-3-*propyl*-1H-2-*benzopyran* (**40**) *and their Enantiomers.*—To a stirred solution of the alcohol (**13**) (148 mg, 0.72 mmol) in acetonitrile (20 ml) and water (20 ml) was added cerium(IV) ammonium nitrate (870 mg, 1.59 mmol) in water (1.5 ml) during 5 min at room temperature. The solution was stirred for a further 30 min and then extracted with dichloromethane. The residue obtained upon work-up was chromatographed (p.l.c., eluant 15% ethyl acetate–light petroleum) to afford the *pyran* (**38**) as white needles, m.p. 91—91.5 °C (light petroleum) (Found: C, 69.9; H, 8.15. $C_{13}H_{18}O_3$ requires C, 70.25; H, 8.1%); $v_{max.}$ 3 430 cm^{-1} (OH); δ 0.98 (3 H, t, *J* 6 Hz, CH$_3$), 1.4—2.1 (4 H, m, CH$_2$CH$_2$), 3.58 (2 H, m, 3-H and OH, collapses to dt, *J* 2.5 and 8 Hz, on D$_2$O exchange, and further, to d, *J* 8 Hz, on double irradiation at δ 1.67), 3.89 (3 H, s, OCH$_3$), 4.71 (2 H, s, ArCH$_2$), 4.72 (1 H, br d, *J* 8 Hz, 4-H), 6.65 (1 H, d, *J* 8 Hz, 6-H), 6.78 (1 H, d, *J* 8 Hz, 8-H), and 7.21 (1 H, t, *J* 8 Hz, 7-H); *m/z* 204 (*M* − 18, 21%), 150 (100), 149 (66), 133 (86), 132 (54), 117 (38), and 91 (46).

A second band at lower R_F afforded the *pyran* (**40**) as white cubes, m.p. 113—114 °C (light petroleum) (Found: C, 70.2; H, 8.2. $C_{13}H_{18}O_3$ requires C, 70.25; H, 8.1%); $v_{max.}$ 3 435 cm^{-1} (OH); δ 0.99 (3 H, t, *J* 7 Hz, CH$_3$), 1.15—2.05 (4 H, m, CH$_2$CH$_2$), 2.15 (1 H, br s, OH, disappears on D$_2$O exchange), 3.53 (1 H, dt, *J* 2 and 6.5 Hz, 3-H), 3.88 (3 H, s, OCH$_3$), 4.7 (1 H, m, 4-H), 4.67 and 4.87 (each 1 H, d, *J* 15 Hz, ArCH$_2$), 6.64 (1 H, d, *J* 8 Hz, 6-H), 6.78 (1 H, d, *J* 8 Hz, 8-H), and 7.25 (1 H, t, *J* 8 Hz, 7-H); *m/z* 204 (*M* − 18, 10%), 150 (100), 149 (56), 133 (68), 132 (46), 117 (32), and 91 (38).

(3R,4S)-3,4-*Dihydro*-4-*hydroxy*-5,8-*dimethoxy*-3-*propyl*-1H-2-*benzopyran* (**39**) *and* (3R,4R)-3,4-*Dihydro*-4-*hydroxy*-5,8-*dimethoxy*-3-*propyl*-1H-2-*benzopyran* (**41**) *and their Enantiomers.*—The alcohol (**14**) (342 mg, 1.45 mmol) in acetonitrile (25 ml) and water (25 ml) was treated as above with cerium(IV) ammonium nitrate (1.55 g, 2.82 mmol). The residue obtained upon work-up was chromatographed (20% ethyl acetate–light petroleum). The early fractions afforded the crude pyran (**39**) (95 mg, 26%) which was subjected to p.l.c. (15% ethyl acetate–light petroleum). This gave the *pyran* (**39**) (80 mg, 21%). A portion of this material was sublimed and then recrystallised to give white needles, m.p. 74—74.5 °C (cyclohexane) (Found: C, 66.35; H, 7.95. $C_{14}H_{20}O_4$ requires C, 66.65; H, 7.95%); $v_{max.}$ 3 492 cm^{-1} (OH); δ 0.98 (3 H, t, *J* 7 Hz, CH$_3$), 1.2—2.0 (4 H, m, CH$_2$CH$_2$), 3.56 (1 H, dt, *J* 2.5 and 8 Hz, 3-H, collapses to d, *J* 8 Hz, on double irradiation at δ 1.60), 3.70 (1 H, d, *J* 2.5 Hz, OH, disappears on shaking with D$_2$O), 3.77 and 3.86 (each 3 H, s, OCH$_3$), 4.57 and 4.84 (each 1 H, d, *J* 16 Hz, ArCH$_2$), 4.71 (1 H, m, 4-H), and 6.71 (2 H, s, 6- and 7-H). The middle fractions were a mixture containing the quinone (**44**). Later fractions gave rise to material which was rechromatographed (eluant 2.5% ethyl acetate–light petroleum) to give the *pyran* (**41**) (112 mg, 30%) as white needles, m.p. 132—133 °C (2.5% ethyl acetate–light petroleum) (Found: C, 66.4; H, 8.0. $C_{14}H_{20}O_4$ requires C, 66.65; H, 7.95%); $v_{max.}$ 3 507 cm^{-1} (OH); δ 0.98 (3 H, t, *J* 7 Hz, CH$_3$), 1.2—1.9 (4 H, m, CH$_2$CH$_2$), 2.4 (1 H, br s, OH), 3.46 (1 H, dt, *J* 2 and 7 Hz, 3-H), 3.76 and 3.84 (each 3 H, s, OCH$_3$), 4.70 and 4.93 (each 1 H, d, *J* 16 Hz, ArCH$_2$), 4.63 (1 H, m, 4-H), and 6.73 (2 H, s, 6- and 7-H); *m/z* 252 (*M*$^+$, 9%), 180 (100), and 165 (30).

(3R,4S)-3,4-*Dihydro*-4-*hydroxy*-3-*propyl*-1H-2-*benzopyran*-5,8-*quinone* (**42**) *and its Enantiomer.*—The alcohol (**39**) (84 mg,

0.33 mmol) in dioxane (4 ml) containing silver(II) oxide was treated with nitric acid (6M; 0.4 ml) and the mixture was stirred for 4 min. The reaction was terminated by the addition of chloroform (8 ml) and water (2 ml). The whole was partitioned between more chloroform and water. The residue obtained upon work-up (60 mg, 81%) was shown by ^{1}H n.m.r. spectroscopy to be the pure *quinone* (**42**) as an oil. P.l.c. afforded an analytically pure sample (Found: C, 65.1; H, 6.35. $C_{12}H_{14}O_4$ requires C, 64.85; H, 6.3%); $v_{max.}$ 3 460 (OH), and 1 663 and 1 650 cm^{-1} (C=O); δ 0.96 (3 H, distorted t, CH$_3$), 1.2—2.05 (4 H, m, CH$_2$CH$_2$), 3.2—3.6 (2 H, m, 3-H and OH), 4.2—4.75 (3 H, m, ArCH$_2$ and 4-H), and 6.76 (2 H, s, 6- and 7-H).

(3R,4R)-3,4-*Dihydro*-4-*hydroxy*-3-*propyl*-1H-2-*benzopyran*-5,8-*quinone* (**43**) *and its Enantiomer.*—The alcohol (**41**) (65 mg, 0.26 mmol) was oxidatively demethylated as above. The residue obtained upon work-up (56 mg) was recrystallised from light petroleum to give the *product* (**43**) (43 mg, 75%) as yellow rods, m.p. 75—76 °C (Found: C, 64.7; H, 6.3. $C_{12}H_{14}O_4$ requires C, 64.85; H, 6.3%); $v_{max.}$ 3 450 (OH) and 1 654 cm^{-1} (C=O); δ 0.98 (3 H, t, *J* 7 Hz, CH$_3$), 1.2—1.95 (4 H, m, CH$_2$CH$_2$), 2.38 (1 H, br d, *J* 8 Hz, OH, D$_2$O exchangeable), 3.41 (1 H, dt, *J* 2 and 6.5 Hz, 3-H), 4.31 (1 H, dd, *J* 1.5 and 20 Hz, pseudoaxial 1-H), 4.48 (1 H, m, pseudoequatorial 4-H), 4.74 (1 H, d, *J* 20 Hz, pseudoequatorial 1-H), and 6.80 (2 H, s, 6- and 7-H).

3,4-*Dihydro*-5,8-*dimethoxy*-3-*propyl*-1H-2-*benzopyran* (**45**).—The alcohol (**14**) (157 mg, 0.67 mmol) in dry dimethylformamide (30 ml) was treated with potassium t-butoxide (298 mg, 2.67 mmol), the solution was stirred at 60 °C for 25 min, and saturated aqueous ammonium chloride was then added. The residue obtained upon work-up was chromatographed (eluant 30% ethyl acetate–light petroleum) to yield the *product* (**45**) (134 mg, 85%) as white rods, m.p. 74—75 °C (light petroleum) (Found: C, 71.25; H, 8.5. $C_{14}H_{20}O_3$ requires C, 71.2; H, 8.5%); δ 0.96 (3 H, t, *J* 7 Hz, CH$_3$), 1.3—1.85 (4 H, m, CH$_2$CH$_2$), 2.36 (1 H, dd, *J* 11 and 17 Hz, pseudoaxial 4-H), 2.80 (1 H, dd, *J* 3.5 and 17 Hz, pseudoequatorial 4-H), 3.4—3.75 (1 H, m, 3-H), 3.76 and 3.78 (each 3 H, s, OCH$_3$), 4.58 (1 H, d, *J* 17 Hz, pseudoaxial 1-H), 4.94 (1 H, d, *J* 17 Hz, pseudoequatorial 1-H), and 6.62 (2 H, s, 6- and 7-H); *m/z* 236 (*M*$^+$, 31%), 165 (32), 163 (100), 146 (63), and 91 (36).

3,4-*Dihydro*-8-*methoxy*-3-*propyl*-1H-2-*benzopyran* (**46**).—The alcohol (**15**) (104 mg, 0.5 mmol) when treated with potassium t-butoxide as above gave a residue (91 mg) which was chromatographed (p.l.c. 2.5% ethyl acetate–light petroleum). The second of six bands (26 mg, 25%) was the oily *product* (**46**) (Found: C, 75.9; H, 8.9. $C_{13}H_{18}O_2$ requires C, 75.7; H, 8.7%); δ 0.97 (3 H, distorted t, CH$_3$), 1.2—2.0 (4 H, m, CH$_2$CH$_2$), 2.64 (2 H, apparent d, *J* 7 Hz, 4-CH$_2$), 3.3—3.8 (1 H, m, 3-H), 3.78 (3 H, s, OCH$_3$), 4.56 (1 H, d, *J* 16 Hz, pseudoaxial 1-H), 4.91 (1 H, d, *J* 16 Hz, pseudoequatorial 1-H), 6.62 and 6.67 (each 1 H, d, *J* 7.5 Hz, 5- and 7-H), and 7.09 (1 H, t, *J* 7.5 Hz, 6-H); *m/z* 206 (*M*$^+$, 69%), 163 (25), 148 (39), 135 (100), 134 (100), 105 (53), 104 (93), and 91 (46).

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