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QUINONES AND QUINONE METHIDES—II
CYCLIZATION AND HYDRATION REACTIONS OF 2-CINNAMYL-5-METHOXY-1,4-BENZOQUINONES

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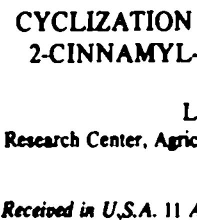
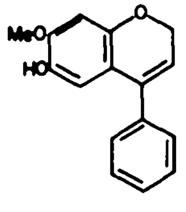
Abstract—4-Methoxydalbergione, a constituent of *Dalbergia* species, is stable in neutral solvents, although it cyclizes quantitatively in basic media to dalbergichromene. The isomeric 2-cinnamyl-5-methoxybenzoquinone is highly labile. It cyclizes in boiling benzene to 7-methoxy-6-hydroxyflav-3-ene, slowly dimerises in acetone, and decomposes in aqueous solvents to at least thirteen unidentified monomeric and oligomeric products. In weakly basic media it forms the flavene and two unstable quinols which have been isolated and structurally identified as their crystalline benzoates. It is suggested that the absence of cinnamyl-quinones or identifiable derivatives in *Dalbergia* species is due to their facile polymerization, and that they may be the precursors of the condensed tannins in these species.

In Dalbergia species neoflavanoid quinones, e.g. 4-methoxydalbergione **1a** and 4,4′-dimethoxydalbergione **1b**, co-occur with quinols **2a** and cyclized derived products, e.g. 4-phenylchromenes **3** and 4-phenylcoumarins. Since related cinnamylphenols, e.g. isoviolastyrene **4** also occur in these plants it has been proposed[1] that the neoflavanoids and cinnamylphenols are biosynthesized from a common phenolic precursor by initial C-alkylation with cinnamylpyrophosphate:

1a : R=H
b : R=OMe



2a : R=H
b : R=OMe



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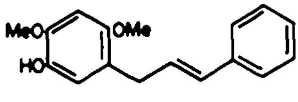

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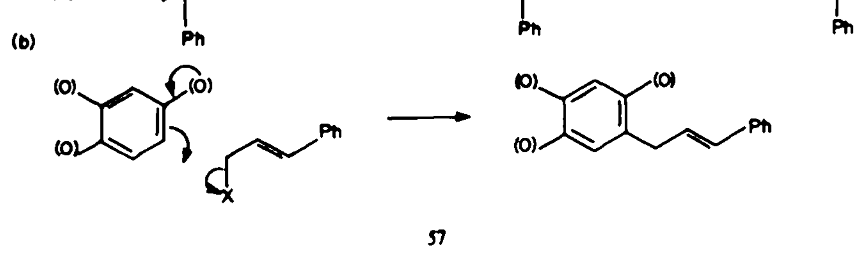
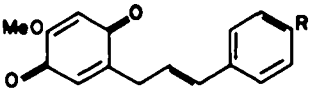


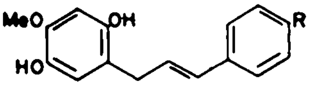
Although technical difficulties have so far precluded attempts to test this proposal by incorporation of radiolabeled precursors, its validity is well supported on mechanistic[2-4] and phytochemical grounds.[5] However, this biogenetic scheme does suggest the need to consider two points which do not appear to have been raised previously, viz: (a) the fact that neither 2-cinnamyl-5-methoxyquinones **5a**, **5b**, which are isomeric with natural dalbergiones, nor identifiable derivatives, such as their cyclization products, have been detected in *Dalbergia* or in any other plant species, and (b) cinnamylquinols **6** isomeric with the natural neoflavanoid quinols **2** have not been found; none of the known natural cinnamylphenols[6] contain an OH *ortho* to the cinnamyl group, although *ortho* methyl ethers such as **4** are known. We have now shown that whereas neoflavanoid quinones of type **1** are relatively stable, the isomeric cinnamylquinones undergo facile cyclization, hydration, and dimerization reactions. Since the initial products of these reactions are themselves highly reactive, leading to amorphous self condensation products, the absence of recognizable cinnamylquinones or derivatives in *Dalbergia* species does not invalidate the Ollis–Gottlieb theory. In fact, this ability to polymerize suggests that the ill-defined polymeric "tannins" which occur in *Dalbergia* heartwoods may be the biogenetic end products of transient, labile cinnamylquinones arising initially from the alkylation of hydroxyquinol.

2-Cinnamyl-5-methoxy-1,4-benzoquinone **5a**, prepared almost quantitatively by silver oxide oxidation of the quinol **6a**, cyclizes readily in boiling benzene solutions to give, in addition to small amounts of amorphous material, high yields of a colorless crystalline compound, identified as 6-hydroxy-7-methoxyflav-3-ene 7a. In accord with this structure the product becomes yellow in HCl fumes, forms monomethyl and monobenzoyl derivatives, and its NMR spectrum shows the presence of three AMX protons (δ5.68, 1H, dd, J = 9, 3.5 Hz; δ5.82, 1H, dd, J = 3.5, 1.5 Hz; δ6.44, 1H, dd, J = 9, 1.5 Hz) which may be assigned[7] to the protons at positions 2, 3 and 4 respectively of a flav-3-ene. In addition, the compound forms a flavan 8a on catalytic hydrogenation, and disproportionates in aqueous perchloric acid to yield the flavylium salt 9 and in small amount, the flavan 8a. Borohydride reduction of 9 gives a crystalline isomer of 7a. It is well established that borohydride reduction of flavylium salts[8] yields flav-2-enes, and in agreement with structure 10 the NMR spectrum of the flavylium reduction product shows a doublet at δ3.50 (J = 4 Hz) for the C_4 methylene protons and a triplet at δ5.47 (J = 4 Hz) for the C_3 vinyl proton. Since the cyclization of isopentenyl-quinones and the dimerization of methyl-quinones are believed to involve initial formation of tautomeric *ortho*-quinone methides,[9,10] the thermal rearrangement of 5a to 7a is presumed to proceed via an unstable *ortho*-quinone methide intermediate 11 or 12, although direct evidence for this is lacking. When monitored at intervals by TLC no intermediates in the change were detected, while an attempt to "trap" an *ortho*-quinone methide as a 2-ethoxychroman by conducting the thermal reaction in benzene containing ethyl vinyl ether[11] gave only 7a. Because of less extended conjugation it would be anticipated that the *ortho*-quinone methide tautomer 13 of 1a should be less stable, and hence not as easily formed as that (11 or 12) from the cinnamylquinone. In confirmation of this, 4-methoxydalbergione does not thermally cyclize in benzene, and it was recovered quantitatively after prolonged refluxing in this solvent.

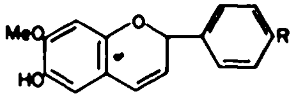
Although 4-methoxydalbergione does not isomerise in boiling benzene, it cyclizes almost quantitatively in N,N-dimethylaminopyridine[12] or pyridine[13] to the natural 4-phenylchromene 3. In contrast to the absence of reported side-products in the base-catalyzed cyclization of dalbergiones, the cinnamylquinone 5a rapidly decomposes in weakly basic solutions to give a complex mixture of monomeric and, eventually, oligomeric compounds. Thus, TLC on silicic acid indicates that in methanol



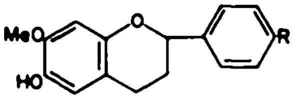
5a : R—H
b : R—OMe



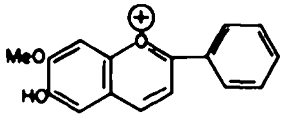
6a : R—H
b : R—OMe



7a : R—H
b : R—OMe



8a : R—H
b : R—OMe



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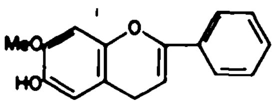

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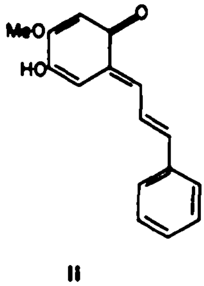

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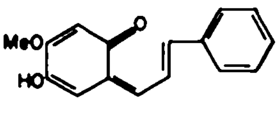

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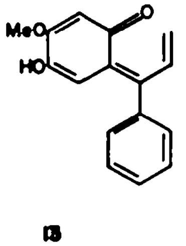

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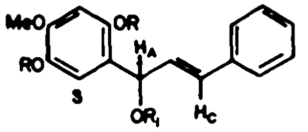
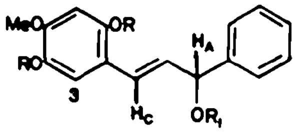
solutions containing sodium acetate or traces of KOH **5a** is converted within a few minutes to a mixture of the flavene **7a**, two easily-oxidized quinols of similar polarity (major products), and traces of other unidentified compounds. After two days at room temperature the initially formed quinols disappear and a dark, highly insoluble solid precipitates. Chromatography of the reaction filtrate then shows the presence of at least seven products. Two quinols are also formed by treatment of **5a** with wet pyridine. Although these could not be isolated and crystallized, they were converted into stable benzoates by addition of benzoyl chloride to the heated pyridine reaction mixture. After warming with acidified methanol the benzoylated mixture fractionally crystallized to give the benzoate of flavene **7a**, two isomeric dimethoxy-dibenzoates, $C_{31}H_{26}O_7$, m.p. 165–166° (major product) and m.p. 139°, and traces of monomethoxy-tribenzoate, $C_{37}H_{28}O_7$, m.p. 194–195°. Treated with pyridine and benzoyl chloride at room temperature with subsequent methanolysis of the product **5a** forms in high yield an approximately equimolar mixture of the two isomeric dibenzoates. Under these conditions only traces of the flavene benzoate are formed.



14a : R=R$_1$=H
b : R=COPh; R$_1$=Me
c : R=COPh; R$_1$=Et
d : R=R$_1$=COPh



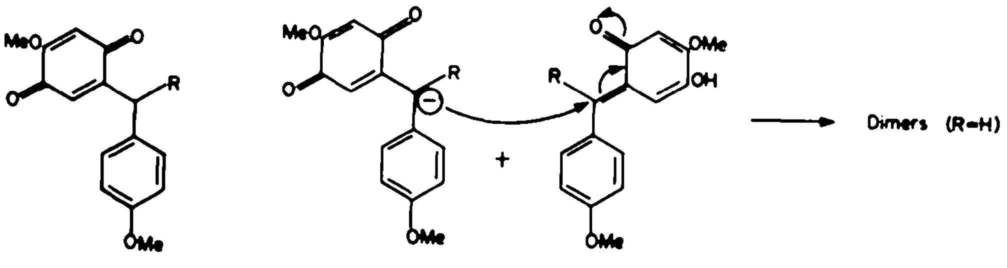
15a : R=R$_1$=H
b : R=COPh; R$_1$=Me
c : R=COPh; R$_1$=Et
d : R=R$_1$=COPh

In accord with structure **14b** the NMR spectrum of the dibenzoate, m.p. 165–166°, shows the presence of an alcoholic OMe group (δ3.35), an aromatic OMe group (δ3.82), a methine proton (δ4.96, 1H, d, J = 6 Hz), coupled to an olefinic proton (δ6.19, 1H, dd, J = 16, 6 Hz) which is in turn coupled to a *trans* olefinic proton (δ6.52, 1H, d, J = 16 Hz). Two para-coupled aromatic protons appear at δ6.86 and δ7.38, five phenyl ring protons as a singlet at δ7.24, and the ten aromatic protons of the two benzoyl groups as multiplets at δ7.40–δ7.68 (6H) and δ8.10–δ8.20 (4H). Location of the alcoholic methoxyl group in **14b** was confirmed by nuclear magnetic double resonance. Irradiation of the methine H$_A$ proton (δ4.96) gave significant sharpening of the aromic H$_3$ proton (δ7.38) signal by elimination of allylic coupling. Irradiation of the olefinic H$_c$ proton (δ6.52) had no effect on the H$_3$ proton signal. Except for differences in the chemical shifts of the methine and vinyl protons the NMR spectrum of the isomeric dibenzoate, m.p. 139°, closely corresponds to that of the dibenzoate, m.p. 165–166°, indicating that this dibenzoate is the alternate isomer **15b**. In accord with structure **15b** irradiation of the methine H$_A$ proton (δ4.73) of this lower melting benzoate did not affect the signal of the aromatic H$_3$ proton (δ7.38), whereas irradiation of the olefinic H$_C$ proton (δ6.62) eliminated allylic coupling and sharpened the H$_3$ signal. The NMR spectrum of the tribenzoate, m.p. 194–5°, is similar to those of the dibenzoates except that it shows a single aromatic OMe group and pronounced downfield shift of the methine proton to δ6.60 and the *trans* olefinic protons to δ6.27 and δ6.73. This tribenzoate, therefore, is either **14d** or **15d**. An allylic OMe (or OH) group conjugated with two phenyl rings as in **14b** and **15b** would, of course, be expected to be extremely labile, and this was confirmed by recrystallizing the dimethoxy-dibenzoate **14b** from ethanol containing a trace of acid. The corresponding monomethoxy-monoethoxy compound **14c** (or **15c**) was obtained. Furthermore, the mass spectra of the isomeric dibenzoates **14b** and **15b** were identical. In addition to the M$^+$ ion at 494 both showed a prominent ion at *m/e* 462 (M$^+$ − 32) indicative of initial loss of methanol. As expected, the dibenzoates **14b** and **15b** cannot be distinguished by zinc dust reduction in acidified methanol, since both yield a mixture (inseparable) of **6a** dibenzoate and its isomer, 5 - methoxy - 2 - (3 - phenyl - 1 - propenyl) - 1,4 - benzene diol dibenzoate. On the basis of the structures of these benzoyl derivatives it is clear that the quinols initially formed from the cinnamylquinone **5a** in basic media are allylic alcohols **14a** and **15a** or their methyl ethers resulting from addition of water or methanol to the quinone methide **11** or **12**.

Extensive decomposition of **5a** leading to the formation of insoluble solids occurs even in non-basic media. Although these reactions have not yet been studied in detail because of the complex mixtures formed, mass spectral measurements show that the insoluble dimeric products are formed in a number of solvent systems. **5a** is unstable in boiling aqueous ethanol and after 50 hr its solution deposits a dark, highly insoluble solid (mol. weight 500–530). TLC of the aqueous alcoholic reaction filtrate then shows complete conversion of **5a** into a mixture of the flavene and at least 13 other compounds. 4-Methoxydalbergione is relatively stable in aqueous ethanol under the same conditions; after 50 hr at reflux NMR analysis of the reaction mixture showed only 2 materials, starting material (80%) and the 4-phenylchromene **3** (20%).

In a related investigation we have observed that 2 - (4 - methoxybenzyl) - 5 - methoxy - 1,4 - benzoquinone **16a** rapidly dimerizes in basic media to give high yields of novel products whose structures have not yet been established with certainty. However, as previously reported[10] for methylbenzoquinones and methylnapthaquinones, the dimerization of **16a** may involve initial attack of its carbanion **17a** on the tautomeric ortho-quinone methide **18a**.

α - Alkyl - benzyl - 1,4 - benzoquinones such as dihydro - 4,4′ - dimethoxydalbergione **16b**, however, do *not* dimerize under the same conditions, e.g. **16b** is unaffected on warming with pyridine, and in ethanolic KOH it is merely converted into dihydro - 4 - ethoxy - 4′ - methoxydalbergione. The inability of **16b** to dimerize indicates that the alkyl substituent may sterically inhibit

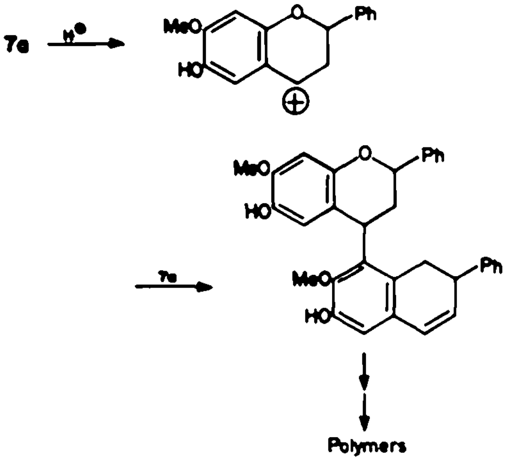


17a : R=H
b : R=Et

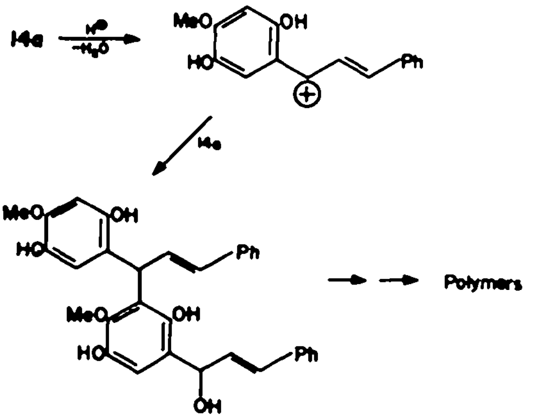
18a : R=H
b : R=Et

a subsequent reaction between the carbanion 17b and *ortho*-quinone methide 18b. From this observation the pronounced differences in the chemical behavior of dalbergiones and cinnamylquinones can be rationalized. Thus, the steric location of the vinyl group in the *ortho*-quinone methide 13 from 4-methoxydalbergione inhibits its dimerization or polymerization, but favors its cyclization to 3. The ortho-quinone methide 11 or 12 from 5a may not only cyclize but also undergo competitive dimerization and hydration reactions. Furthermore, flavenes 7 and quinols 14, 15 initially formed from cinnamylquinones are labile compounds, which would be expected to polymerize by reactions similar to those known to be involved[14] in the formation of condensed plant tannins from catechins and flavan-3,4-diols, e.g.

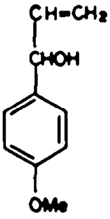
(a)



(b)



Like 5a the cinnamylquinone 5b, isomeric with natural 4,4′-dimethoxydalbergione 1b, is unstable. It rapidly cyclizes in boiling benzene to the flavene 7b (an oil) which on catalytic hydrogenation yields the flavan 8b. For the synthesis of 5b, methoxyquinol was condensed with (±) - 1 - (4 - methoxyphenyl) - allyl alcohol 19 to yield the cinnamylphenol 6b and 3 - (4 - methoxycinnamyl) - 6 - hydroxy - 4′,7 - dimethoxyflavan 20. The formation of 3-cinnamylflavans related to 20 in similar alkylation reactions has been well established.[4,16] Oxidation of 6b with silver oxide in acetone then gave the quinone 5b.



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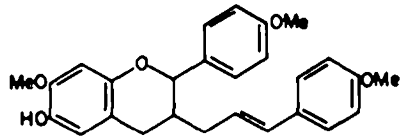

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EXPERIMENTAL

All m.ps are uncorrected. NMR spectra were determined in $CDCl_3$ with a TMS internal standard on a modified Varian HA-100 instrument. UV spectra were determined in EtOH.

2-*Cinnamyl-5-methoxybenzoquinone*, 5a

A soln of 2-cinnamyl-5-methoxyquinol[4] (10 g) in ether (500 ml) was stirred at room temp. for 5 hr with Ag_2O (20 g). The solid was filtered and extracted with warm acetone (3 × 200 ml). The combined ether and acetone solns were concentrated, diluted with MeOH and re-concentrated until crystallization of the quinone began. Recrystallized from acetone methanol 5a was obtained as golden yellow needles, m.p. 137° (9.0 g). (Found: C, 75.4; H, 5.52. Calc. for $C_{16}H_{14}O_3$: C, 75.6; H, 5.55%); λ_{max} 368 (3.24), 257 (4.45) nm (log ε); NMR spectrum: δ3.33, 2H, dd, J = 7, 1 Hz; δ3.80, 3H, s; δ5.94, 1H, s; δ6.15, 1H, dt, J = 7, 16 Hz; δ6.50, 1H, d, J = 16 Hz; δ6.55, 1H, t, J = 1 Hz; δ7.18–δ7.36, 5H, m.

6-*Hydroxy-7-methoxyflav-3-ene* 7a

A soln of 5a (20 g) in benzene (400 ml) was heated under reflux for 22 hr, and evaporated. A soln of the residue in ether (100 ml) was diluted with warm Skelly solve F (500 ml), filtered from a small quantity of flocculent solid, and concentrated. The crystals which separated on cooling were recrystallized from ether-Skelly solve F to give 7a as cream-colored, glistening needles, m.p. 84–85° (15.1 g). (Found: C, 75.4; H, 5.58. Calc. for $C_{16}H_{14}O_3$: C, 75.6; H, 5.55%); λ_{max} 328 (3.80) 236 (4.57) 220 (4.28) nm (log ε);

NMR spectrum: δ3.81, 3H, s; δ5.18, 1H (OH), s; δ5.68, 1H, dd, J = 9, 3.5 Hz; δ5.82, 1H, dd, J = 3.5, 1.5 Hz; δ6.40, 1H, s; δ6.44, 1H, dd, J = 9, 1.5 Hz; δ6.61, 1H, s; δ7.26–δ7.52, 5H, m.

A soln of 5a (2.0 g) in benzene (40 ml) containing ethyl vinyl ether (10 ml) heated under reflux for 24 hr and worked up as described above gave the flavene 7a, m.p. and m.m.p. 84–85° (1.2 g).

A mixture of 7a, dimethyl sulfate (2.0 ml), K_2CO_3 (5 g) and acetone (30 ml) was refluxed for 1 hr. The mixture was concentrated, diluted with water and, after hydrolysis of excess dimethyl sulfate, extracted with ether. The ether soln was diluted with a large volume of Skelly solve F, concentrated and cooled. The crystalline product was recrystallized from Skelly solve F to give 6,7-*dimethoxyflav-3-ene* as colorless, glistening plates, m.p. 81–82° (0.41 g). (Found: C, 76.2; H, 5.98. Calc. for $C_{17}H_{16}O_3$: C, 76.1; H, 6.01%); NMR spectrum: δ3.81, 3H, s; δ3.84, 3H, s; δ5.68, 1H, dd, J = 9, 3.5 Hz; δ5.86, 1H, dd, J = 3.5, 1 Hz; δ6.43, 1H, s; δ6.46, 1H, dd, J = 9, 1 Hz; δ6.57, 1H, s; δ7.30–δ7.54, 5H, m.

Compound 7a (0.20 g), treated with benzoyl chloride (0.5 ml) and pyridine (0.5 ml) gave 7a *monobenzoate*, colorless needles (from MeOH), m.p. 130–131° (0.15 g). (Found: C, 76.9; H, 5.15. Calc. for $C_{23}H_{18}O_4$: C, 77.0; H, 5.06%); NMR spectrum: δ3.74, 3H, s; δ5.69, 1H, dd, J = 9.5, 3.5 Hz; δ5.92, 1H, dd, J = 3.5, 1.5 Hz; δ6.46, 1H, dd, J = 9.5, 1.5 Hz; δ6.50, 1H, s; δ6.83, 1H, s; δ7.28–δ7.64, 8H, m; δ8.16–δ8.27, 2H, m.

6-*Hydroxy-7-methoxyflavan* 8a

Compound 7a (0.5 g) was hydrogenated in THF (30 ml) at room temp. and 20 psi with 5% Pd-C catalyst. The product crystallized from Skelly solve to give 8a as colorless needles, m.p. 110–111° (0.41 g). (Found: C, 74.9; H, 6.37. Calc. for $C_{16}H_{16}O_3$: C, 75.0; H, 6.29%); NMR spectrum: δ2.18, 2H, m; δ2.85, 2H, m; δ3.85, 3H, s; δ4.99, 1H, dd, J = 9, 4 Hz; δ5.22, 1H (OH), s; δ6.50, 1H, s; δ6.65, 1H, s; δ7.40, 5H, s.

6-*Hydroxy-7-methoxyflavylium perchlorate*, 9

Compound 7a (2.0 g) was heated on a steam-bath with 35% aqueous perchloric acid (20 ml) for 30 min. Excess of ether was added to the cooled mixture and the yellow crystalline solid was collected (1.1 g). Recrystallized from acetic acid–aqueous perchloric acid.

6-*Hydroxy-7-methoxyflavylium perchlorate* separated as yellow needles, m.p. 255–256°. (Found: C, 54.6; H, 3.92. Calc. for $C_{16}H_{14}O_7Cl$: C, 54.4; H, 3.99%). The ether soln from the reaction was evaporated and the residue crystallized from Skelly solve F to give 8a (0.06 g), m.p. and m.m.p. 110–111° (Found: C, 75.0; H, 6.30%).

6-*Hydroxy-7-methoxyflav-2-ene* 10

$NaBH_4$ (0.4 g) was added to a suspension of 6-hydroxy-7-methoxyflavylium perchlorate (1.0 g) in MeOH (20 ml) at 5°. After 10 min water (100 ml) and 5% $NaHSO_3$ aq (5 ml) were added. The solid product crystallized from Skelly solve F to yield 10 as colorless needles, m.p. 112–113°. (Found: C, 75.8; H, 5.67. Calc. for $C_{16}H_{14}O_3$: C, 75.6; H, 5.55%); λ_{max} 298 (4.16) 244 (2.70) nm (log ε); NMR spectrum: δ3.50, 2H, d, J = 4 Hz; δ3.89, 3H, s; δ5.36, 1H (OH), s; δ5.47, 1H, t, J = 4 Hz; δ6.60, 1H, s; δ6.64, 1H, s; δ7.28–δ7.78, 5H, m.

Dalbergichromene 3

(a) 4-Methoxydalbergione 1a (2.0 g), heated in puridine as described,[13] gave 3, colorless needles from Skelly solve F, m.p. 99° (lit.[13] m.p. (99–100°) (1.65 g); NMR spectrum: δ3.87, 3H, s; δ4.77, 1H, d, J = 4 Hz); δ5.20, 1H, s; δ5.71, 1H, t, J = 4 Hz; δ6.53, 1H, s; δ6.64, 1H, s; δ7.36, 5H, s. 1a, m.p. 125°, was recovered quantitatively when its soln (1.0 g) in benzene (20 ml) was heated under reflux for 20 hr, concentrated, and diluted with Skelly solve F.

(b) A soln of 1a (0.1 g) in EtOH (15 ml) and water (1 ml) was heated under reflux for 48 hr, diluted with water, and extracted with ether. TLC of the ether extract showed the presence only of 1a and 3 (ratio 4:1 by NMR analysis). The residue obtained on evaporation of the ether was dissolved in Skelly solve F. On concentration unreacted 1a crystallized as yellow needles, m.p. and m.m.p. 124–125°. Further concentration gave 3 as colorless needles, m.p. and m.m.p. 99°.

The cinnamylquinone 5a (2.0 g) treated with EtOH (150 ml) and water (5 ml) under the same conditions decomposed. Evaporation of the mixture gave a dark gum which was extracted with ether. The dark ether-insoluble product (0.35 g) consists (TLC analysis) of one green-blue and five red-blue high molecular weight compounds. The ether soluble fraction consisted of a mixture of the flavene 10 and at least eight other compounds which were not identified.

Hydration of 5a

(a) Compound 5a (1.5 g) was warmed with pyridine (3.0 ml) containing water (5 drops) until a clear soln resulted (3 min). Benzoyl chloride (3.0 ml) was then added and after 5 min the mixture was diluted with water. Following hydrolysis of excess benzoyl chloride the oily product was collected and digested with MeOH containing a drop of conc. HCl. The undissolved solid was filtered and recrystallized from acetone–MeOH to give the *tribenzoate* 14d *or* 15d as colorless needles, m.p. 194–195° (0.022 g). (Found: C, 75.7; H, 4.86. Calc. for $C_{37}H_{28}O_7$: C, 76.0; H, 4.83%); NMR spectrum: δ3.81, 3H, s; δ6.27, 1H, dd, J = 15.5, 6 Hz; δ6.60, 1H, d, J = 6 Hz; δ6.73, 1H, d, J = 15.5 Hz; δ6.87, 1H, s; δ7.16–δ7.76, 15H, m; δ7.90–δ8.26, 6H, m.

The MeOH soln of the benzoylated mixture, from which the tribenzoate had been filtered, deposited a crystalline mixture (0.80 g) of two dibenzoates on standing. Fractionally recrystallized from MeOH, 14b, m.p. 165–166°, separated first as colorless needles (0.54 g) was purified by recrystallization from acetone–MeOH. (Found: C, 75.7;H, 5.38. Calc. for $C_{31}H_{26}O_6$: C, 75.3; H, 5.30%); NMR: δ3.35, 3H, s; δ3.82, 3H, s; δ4.96, 1H, d, J = 6 Hz; δ6.19, 1H, dd, J = 16, 6 Hz; δ6.52, 1H, d, J = 16 Hz; δ6.86, 1H, s; δ7.23, 5H, s; δ7.38; 1H, s; δ7.40–δ7.68, 6H, m; δ8.10–δ8.30, 4H, m; *m/e* (%): 494 (1.4), 462 (3.0), 389 (7.9), 373 (4.5), 358 (2.3), 105 (100).

The more soluble dibenzoate crystallized on further concentration of the MeOH soln, and was recrystallized from MeOH to give 15b as colorless needles, m.p. 139° (0.15 g). (Found: C, 75.0; H, 5.38. Calc. for $C_{31}H_{26}O_6$: C, 75.3; H, 5.30%); NMR spectrum: δ3.30, 3H, s; δ3.82, 3H, s; δ4.73, 1H, d, J = 7 Hz; δ6.18, 1H, dd, J = 16, 7 Hz; δ6.62, 1H, d, J = 16 Hz; δ6.86, 1H, s; δ7.26, 5H, s; δ7.38, 1H, s; δ7.10–δ7.40, 6H, m; δ8.10–δ8.30, 4H, m; *m/e* (%): 494 (1.9), 462 (1.9), 389 (7.6), 373 (3.8), 358 (2.6), 105 (100).

The MeOH filtrate from the crude mixture of dibenzoates was evaporated to an oil which crystallized from Skelly solve F (0.35 g). Recrystallized from MeOH the *benzoate* of 7a separated as colorless needles, m.p. and m.m.p. 131°.

A soln of the dibenzoate (m.p. 165°) in EtOH containing a drop of HCl was heated to boiling and allowed to cool. The crystalline product was recrystallized from Skelly solve F and from EtOH to give the *monoethoxy-monomethoxydibenzoate* 14e or 15e as colorless needles, m.p. 127–128°. (Meas. mass = 508.1903. Calc. for $C_{32}H_{28}O_6$ = 508.1887); NMR spectrum: δ1.14, 3H, t, J = 7 Hz; δ3.47, 2H, q, J = 7 Hz; δ3.81, 3H, s; δ4.83, 1H, d, J = 6 Hz; δ6.19, 1H, dd, J = 16, 6 Hz; δ6.60, 1H, d, J = 16 Hz; δ6.85, 1H, s; δ7.25, 5H, s; δ7.37, 1H, s; δ7.40–δ7.70, 6H, m; δ8.10–δ8.26, 4H, m.

(b) Compound 5a (2.0 g) was dissolved in a mixture of pyridine (8 ml) and benzoyl chloride (4 ml) at room temp. After 1.5 hr excess of water was added. The oily product was washed with dilute aqueous HCl and water and dissolved in boiling MeOH (60 ml). On cooling colorless crystals, m.p. 130–155°, of an approximately equimolar mixture (by NMR analysis) of 14b and 15b separated (3.2 g). This mixture was converted almost quantitatively into the less soluble, higher melting isomer by treating its solution (2 g) in acetone–MeOH (50%; 100 ml) with a drop of HCl. On concentration and cooling the dibenzoate 14b, m.p. and m.m.p. 165° crystallized (1.6 g).

5 - *Methoxy* - (3 - *phenyl* - 2 - *propenyl*) - 1,4 - *benzene diol dibenzoate*

(a) A soln of 6a (0.1 g) in pyridine (1.0 ml) and benzoyl chloride (1.0 ml) was warmed for 5 min and diluted with water. The product crystallized from MeOH to give the *dibenzoate* of **6a** as colorless prisms m.p. 147–148°. (Found: C, 77.5; H, 5.25. Calc. for $C_{30}H_{24}O_5$: C, 77.6; H, 5.21%); NMR spectrum: δ3.48, 2H, d, J = 6 Hz; δ3.82, 3H, s; δ6.28, 1H, dt, J = 16, 6 Hz; δ6.42, 1H, d, J = 16 Hz; δ6.89, 1H, s; δ7.14, 1H, s; δ7.24, 5H, s; δ7.40–δ7.70, 6H, m; δ8.10–δ8.28, 4H, m.

(b) A soln of **14b** (0.2 g) in THF (5 ml) and MeOH (25 ml) was treated with Zn dust (2 g) and conc HCl (1 ml) and warmed for 5 min. The filtered soln was diluted with water and extracted with ether. The residue obtained on evaporation of the ether crystallized from MeOH to give colorless needles, m.p. 118–119° (0.16 g), consisting of an equimolar mixture of **6a** dibenzoate (by NMR analysis) and its isomer. This mixture of isomeric benzoates was not separated by repeated recrystallization from alcohol.

Dihydro-4-ethoxy-4'-methoxydalbergione

A soln of **16b**[15] (1.8 g) in warm EtOH (50 ml) was treated with 2 drops of 15% KOH aq and kept at room temp. for 20 hr. The crystalline product was recrystallized from acetone-MeOH to give *dihydro-4-ethoxy-4'-methoxydalbergione* as yellow needles, m.p. 104° (1.5 g). (Found: C, 71.7; H, 6.56. Calc. for $C_{18}H_{20}O_4$: C, 72.0; H, 6.71%); NMR spectrum: δ0.88, 3H, t, J = 7.5 Hz; δ1.45, 3H, t, J = 7.5 Hz; δ1.85, 2H, q, J = 7.5 Hz; δ3.77, 3H, s; δ3.98, 3H, m; δ5.84, 1H, s; δ6.50, 1H, d, J = 1.5 Hz; δ6.82, 2H, d, J = 9 Hz; δ7.14, 2H, d, J = 9 Hz.

(±)-1-(4-*Methoxyphenyl*)-*allyl alcohol*

To a soln of vinylmagnesium bromide (0.6 mole) in 250 ml THF was added a soln of anisaldehyde (0.5 mole) in 125 ml of anhyd ether at a rate sufficient to maintain gentle reflux. After 1 hr at reflux the mixture was cooled in an ice bath and sat NH_4Cl aq was added until the salts precipitated leaving a clear supernatant soln. Removal of the solvents from this dried soln at room temp. and reduced pressure yielded a slightly colored oil which could only be distilled successfully if (a) small amounts were employed, (b) free radical inhibitors were added, and (c) pressures of <0.1 Torr were employed. The clear colorless distillate (60% yield) b.p. 100–101° (0.1 Torr.) of (±)-1-(4-methoxyphenyl)-allyl alcohol[17] shows a strong OH absorption in the IR (ν_{max} 3400 cm^{-1}) and has an NMR spectrum consistent with structure **19**: δ3.03, 1H, broad s (OH); δ3.74, 3H, s (OCH_3); δ4.92–5.42, 3H, m (vinyl); δ5.80–6.30, 1H, m (methine), δ6.80, 2H, d, J = 9 Hz (aromatic) and δ7.23, 2H, d, J = 9 Hz (aromatic).

2-(4-*Methoxycinnamyl*)-5-*methoxyquinol* **6b**

To a refluxing soln of methoxyquinol (3.4 g), citric acid (2 g), and ascorbic acid (1 g) in water (100 ml) was added (±)-1-(4-methoxyphenyl)-allyl alcohol (4.0 g). After 2 hr at reflux the mixture was chilled and the semi-solid product was crystallized from benzene (40 ml) to yield **6b** as cream colored platelets, m.p. 145–146° (2.1 g). (Found: C, 71.5; H, 6.43. Calc. for $C_{17}H_{18}O_4$: C, 71.31; H, 6.34%); NMR spectrum (deuterioacetone): δ3.43, 2H, d, J = 6 Hz; δ3.75, 6H, s; δ6.22, 1H, dt, J = 16, 6 Hz; δ6.43, 1H, d, J = 16 Hz; δ6.54, 1H, s; δ6.66, 1H, s; δ6.84, 2H, d, J = 9 Hz; δ7.30, 2H, d, J = 9 Hz; δ7.51, 1H, broad s. With Ac_2O and pyridine **6b** gave a *diacetate*, colorless needles (from MeOH), m.p. 99–100°. (Found: C, 67.9; H, 5.90. Calc. for $C_{21}H_{22}O_6$: C, 68.1; H, 5.99%); NMR spectrum: δ2.28, 6H, s; δ3.35, 2H, d, J = 6 Hz; δ3.79, 6H, s; δ6.05, 1H, dt, J = 16, 6 Hz; δ6.38, 1H, d, J = 16 Hz; δ6.69, 1H, s; δ6.82, 2H, d, J = 9 Hz; δ6.94, 1H, s; δ7.27, 2H, d, J = 9 Hz.

Concentration of the filtrate from **6b** yielded colorless, fine needles, m.p. 150–152°, (1.2 g) of 3-(4-*methoxycinnamyl*)-6-*hydroxy*-4,7-*dimethoxyflavan*; ms: M⁺ obs. *m/e* 432.1925. Calc. for $C_{27}H_{28}O_5$ *m/e* 432.1936; NMR spectrum: δ1.70–δ2.30, 3H, m; δ2.40–δ2.90, 2H, m; δ3.77, 9H, s; δ4.64, 1H, d, J = 8 Hz; δ5.21, 1H, s; δ5.88, 1H, dt, J = 16, 6 Hz; δ6.24, 1H, d, J = 16 Hz; δ6.44, 1H, s; δ6.60, 1H, s; δ6.76–δ7.26, 8H, m.

With Ac_2O and pyridine a non-crystalline monoacetate was formed from the flavan; ms: M bbs. *m/e* 474.2025. Calc. for $C_{29}H_{30}O_6$ *m/e* 474.2042; NMR spectrum: δ1.70–δ2.32, 3H, m; δ2.28, 3H, s; δ2.40–δ2.96, 2H, m; δ3.74, 3H, s; δ3.78, 3H, s; δ3.81, 3H, s; δ4.68, 1H, d, J = 8 Hz; δ5.87, 1H, dt, J = 16, 6 Hz; δ6.24, 1H, d, J = 16 Hz; δ6.50, 1H, s; δ6.71, 1H, s; δ6.81, 2H, d, J = 9 Hz; δ6.91, 2H, d, J = 9 Hz; δ7.21, 2H, d, J = 9 Hz; δ7.29, 2H, d, J = 9 Hz; mass spectrum *m/e* (rel. abundance): 474 M⁺ (7); 280 (18); 279 (38); 147 (100); 121 (43); 115 (12); 91 (14).

2-(4-*Methoxycinnamyl*)-5-*methoxybenzoquinone* **5b**

A mixture of **6b** (8 g) and Ag_2O (16 g) was refluxed for 10 min in acetone (160 ml), filtered, and the filtrate diluted with MeOH and concentrated to give glistening yellow-bronze platelets of the quinone, m.p. 131–132° (5.2 g). (Found: C, 71.9; H, 5.74. Calc. for $C_{17}H_{16}O_4$: C, 71.8; H, 5.67%); NMR spectrum: δ3.31, 2H, d, J = 7 Hz; δ3.79, 3H, s; δ3.81, 3H, s; δ5.93, 1H, s; δ5.98, 1H, dt, J = 16, 7 Hz; δ6.44, 1H, d, J = 16 Hz; δ6.55, 1H, s; δ6.82, 2H, d, J = 9 Hz; δ7.28, 2H, d, J = 10 Hz.

6-*Hydroxy*-4',7-*dimethoxyflav*-3-*ene* **7b**

A soln of **5b** (2.0 g) in benzene (50 ml) was refluxed under argon for 21 hr and evaporated to dryness. Although TLC indicated that the spot corresponding to **5b** had been replaced with a new material which turned yellow with HCl fumes (typical of flavenes), attempts to obtain a pure sample by crystallization failed because of the lability of the compound. The product was characterized as the corresponding flavan **8b**.

6-*Hydroxy*-4',7-*dimethoxyflavan* **8b**

A freshly prepared sample of crude **7b** (2.0 g) was shaken with Pd-C in EtOH (200 ml) under 3 atmospheres of H_2 for 2 hr. Removal of the solvent from the filtrate and recrystallization of the residue from acetone-cyclohexane gave **8b** as nearly colorless crystals, m.p. 146–147° (1.5 g). (Found: C, 71.4; H, 6.23. Calc. for $C_{17}H_{18}O_4$: C, 71.31; H, 6.34%); NMR spectrum: δ1.90–δ2.20, 2H, m; δ2.5–δ3.1, 2H, m; δ3.80, 6H, s; δ4.91, 1H, dd, J = 8, 5 Hz; δ5.23, 1H, s; δ6.45, 1H, s; δ6.62, 1H, s; δ6.90, 2H, d, J = 9 Hz; δ7.34, 2H, d, J = 9 Hz. Warmed with Ac_2O and pyridine, **8b** gave a monoacetate as colorless needles, m.p. 101–102°. (Found: C, 69.4; H, 6.18. Calc. for $C_{19}H_{20}O_5$: C, 69.50; H, 6.14%).

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