OLIGOMERIC FLAVANOIDS. PART 6*. EVIDENCE SUPPORTING THE INVERSION OF ABSOLUTE CONFIGURATION AT 3-C ASSOCIATED WITH BASE CATALYZED A-/B-RING INTERCHANGE OF PRECURSORS HAVING 2,3-TRANS-3,4-CIS-FLAVAN-3-OL CONSTITUENT UNITS

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ABSTRACT - Whereas the enantiomeric 2,3-trans-3,4-trans-4-arylflavan-3-ols (10) and (12) as biflavanoid models are subject to stereospecific C-ring isomerization under base catalysis, those with 3,4-cis configuration (11) and (13) are transformed stereoselectively via intermediate quinonemethides (20) and (27) to form a range of analogous 4-arylflavan-3-ols with rearranged pyran heterocycles. The inversion of the absolute configuration at 3-C in those isomers possessing interchanged resorcinol A- and pyrocatechol B-rings [eg. (28), (30) vs. (23), (25)] required by the mechanism for their formation, are unequivocally confirmed by comparison of the cd data of the different enantiomeric- and quasi-enantiomeric pairs.

The natural occurrence of phlobatannins, a novel class of oligoflavanoids possessing rearranged pyran heterocycles, has recently been demonstrated[1]. These functionalized tetrahydropyranochromenes are smoothly generated by mild base treatment of their apparant biflavanoid precursors[2]. Whereas profisetinidins with 3,4-trans-flavan-3-ol constituent units are subject to stereospecific C-ring isomerization[3,4] {eg. (1)$^{\neq}$ ⟶ [(3)] ⟶ (5)}, those with 3,4-cis 'upper' moieties are transformed stereoselectively to analogues with trans-trans- and cis-trans-configuration of their C-ring[4,5] {eg. (2) ⟶ [(4)] ⟶ (6)-(9)}. Formation of (8) and (9) in which the resorcinol A- and pyrocatechol B-rings are interchanged relative to

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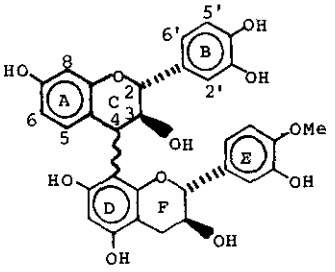
*Part 5. J.F.W. Burger, J.P. Steynberg, D.A. Young, E.V. Brandt, and D. Ferreira, J. Chem. Soc. Perkin Trans. 1, 1988, paper 8/02280A.

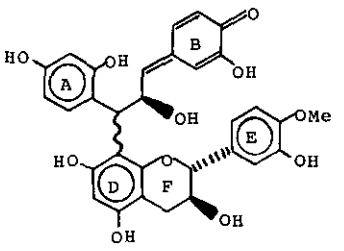
$^{\neq}$Protected at 4-OH(E) to prevent side reactions associated with an E-ring quinonemethide

their positions in homologues (6) and (7) via. 1,3-flavanyl migration in an intermediate quinonemethide (4), requires inversion of the absolute configuration at 9-C [3-C in biflavanoid (2)][5]. Since the sign of the Cotton effect in the



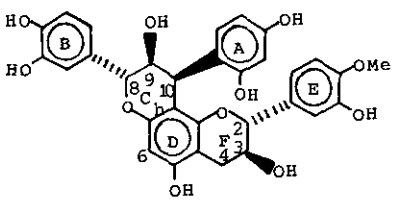
(1) ≡ ⋮⋮⋮

(2) ≡ ▲

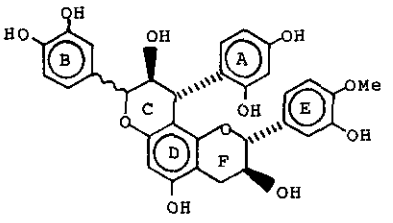


(3) ≡ ⋮⋮⋮

(4) ≡ ▲

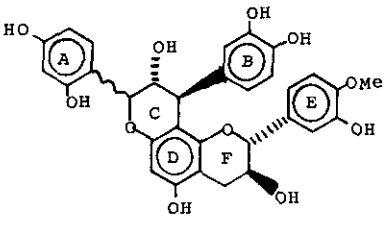


(5)



(6) ≡ ⋮⋮⋮

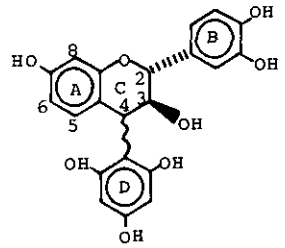
(7) ≡ ▲

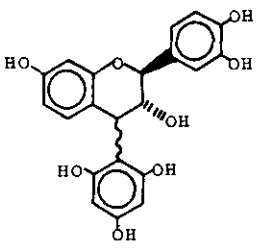


(8) ≡ ⋮⋮⋮

(9) ≡ ▲

220-240 nm region of the cd spectra of these tetrahydropyrano[2,3-h]chromenes is influenced by the conformationally mobile F-ring, the chiroptical method[6] of differentiating the quasi-enantiomeric pairs (6), (7), and (8), (9) proved to be unreliable[4,5]. The readily available 4-arylflavan-3-ols (10) - (13)[7] were therefore selected as appropriate models to unambiguously establish that ring





(10) 

(11) 

(12) 

(13) 

interchange is associated with inversion of the absolute configuration at the chiral centres of ring C.

Separate treatment of the 2,3-trans-3,4-trans-enantiomers (10) and (12) with 0.025 M $NaHCO_3$-0.025 M Na_2CO_3 buffer (pH10) under nitrogen for 8h at 50°C gave the anticipated stereospecific conversion[3] to the rearranged 2,3-trans-3,4-cis-4-arylflavan-3-ols (15) and (18) via intermediate quinonemethides (14) and (17) (scheme 1)*. Comparison of ^{1}H nmr ($J_{2,3}$ 10.5, $J_{3,4}$ 6.0 Hz) and cd data of the hexamethyl ether acetate (16) with those of the derivative obtained by acid catalyzed coupling of (+)-leucocyanidin and resorcinol[7] proved their identity. Involvement of one of the phloroglucinol hydroxy groups in the pyran heterocycle of (16) and simultaneous 'liberation' of a resorcinol hydroxy group in (10) are demonstrated by nOe experiments which indicate association of 2-OMe(A) with 3-H(A), 4-OMe(A) with both 3- and 5-H(A), 5-OMe(D) with 6-H(D), and of 7-OMe(D) with both 6- and 8-H(D)†. The hexamethyl ether acetate (19) of the novel enantiomer (18)

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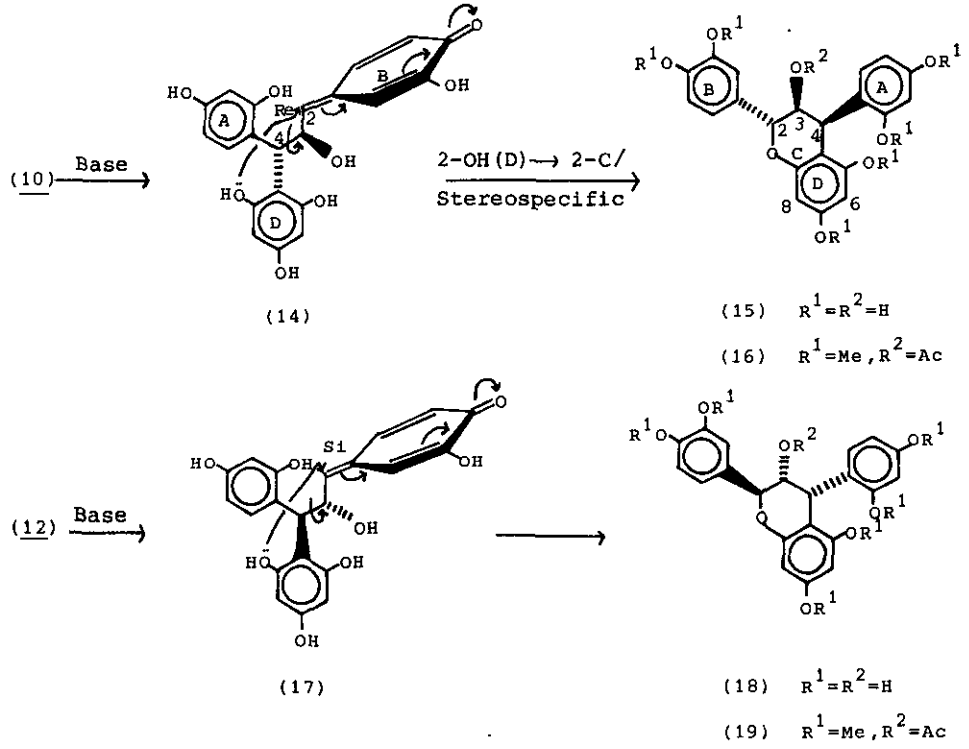
*To facilitate direct comparison with biflavanoid (1) pyran recyclization via 2-OH(D) [equivalent of 7-OH(D) in (1)] is indicated. Designation of rings A-D in (15) is retained for similar reasons.

†This method to define the nature of the phloroglucinol and resorcinol units was used throughout this paper.

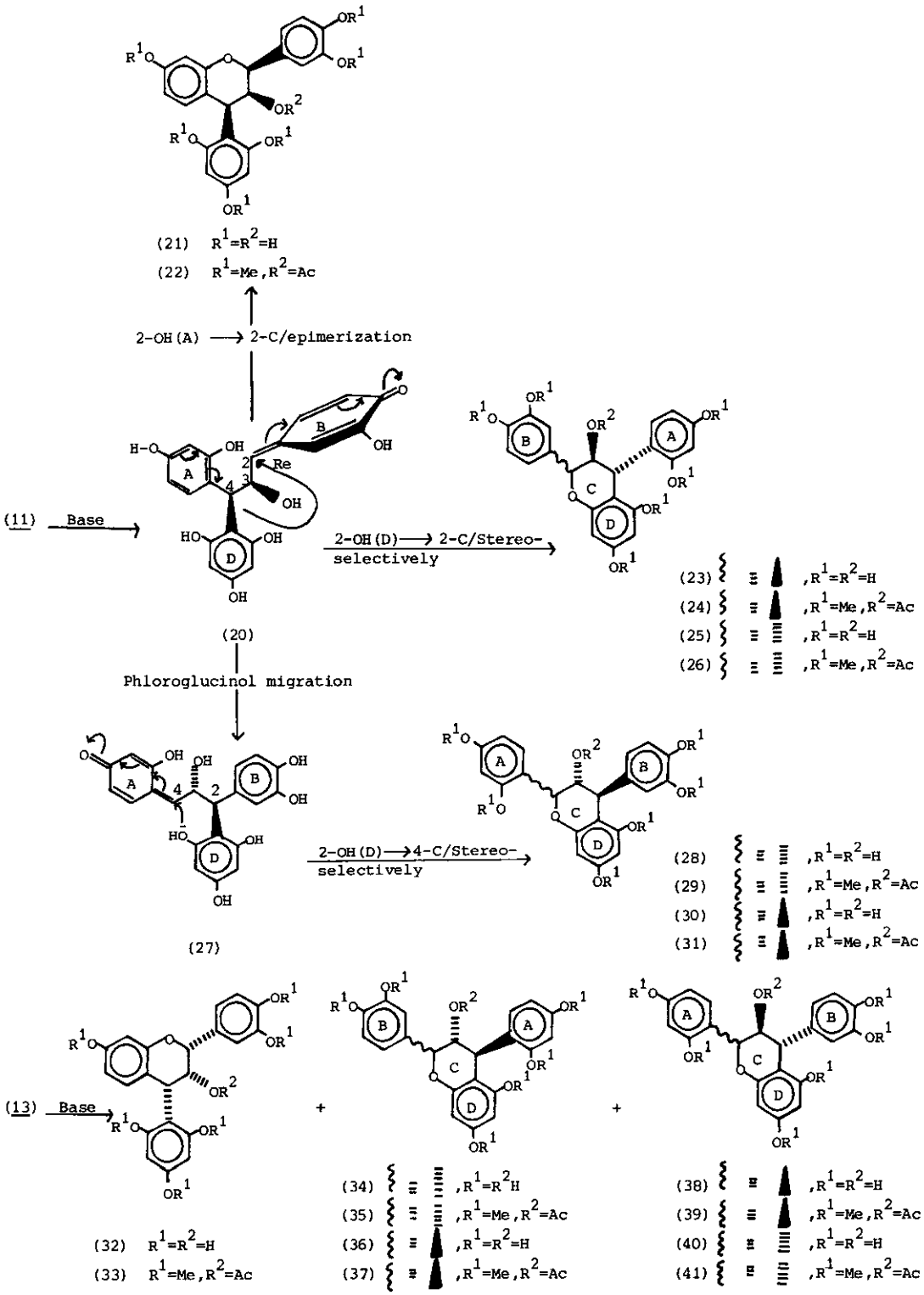
exhibits identical ^{1}H nmr data but opposite circular dichroic Cotton effects compared to those of (16).



Scheme 1. Base catalyzed conversion of the 2,3-trans-3,4-trans-4-arylflavan-3-ols (10) and (12).

Similar treatment of the 2,3-trans-3,4-cis-4-arylflavan-3-ol enantiomers (11) and (13) gave mixtures comprising of the 2,3-cis-3,4-cis-[(21), (32)], 2,3-cis-3,4-trans-[(23), (34)], 2,3-trans-3,4-trans-4-arylflavan-3-ols[(25), (36)], as well as the cis-trans-[(28), (38)], and all-trans-[(30), (40)] analogues with interchanged resorcinol A- and pyrocatechol B-rings relative to their positions in homologues (23), (34), and (25), (36) (scheme 2). Owing to the complexity of the phenolic mixtures, the C-ring isomerized compounds were identified as their hexamethyl ether acetates.

^{1}H Nmr coupling constants of C-ring protons ($J_{2,3}$ ca 1.0, $J_{3,4}$ 5.0 Hz - table 1) of (22) are consistent with 2,3-cis-3,4-cis relative configuration[6,8] of this



Scheme 2. Base catalyzed conversions of the 2,3-trans-3,4-cis-4-arylflavan-3-ols (11) and (13)

heterocycle. Linkage of the pyrocatechol unit to 2-C and of the phloroglucinol moiety to 4-C was confirmed by spin decoupling experiments using the 2- and 4-H resonances (δ5.20, 5.51 resp.) as reference signals. Identical ^{1}H nmr data but opposite Cotton effects were observed for enantiomer (33). The sign of the Cotton effect at 236 nm (table 2) when taken in conjunction with coupling constants of heterocyclic protons facilitates definition of absolute configuration[6], i.e. 2S,3S,4R for (22) and 2R,3R,4S for (33). These analogues complement the rare series of synthetic 2,3-cis-3,4-cis-4-arylflavan-3-ols[6].

The relative configuration of the 2,3-cis-3,4-trans derivatives (24) and (35) is confirmed by ^{1}H nmr coupling constants ($J_{2,3}$ ca 1.0, $J_{3,4}$ 2.0 Hz) and by the nOe association (6.1%) of 2-H(C)(δ4.94) with 6-H(A)(δ6.62)[5], the latter effect indicating a preferred sofa conformation in which the 'liberated' resorcinol moiety occupies a near-axial orientation. A significant nOe association (1.1%) between 5-OMe(D)(δ3.59) and 4-H(C)(δ4.48) unequivocally confirms the chemical shift of the latter proton thus enabling location of the resorcinol- and pyrocatechol moieties at respectively 4- and 2-C via the appropriate decoupling experiments. Cd data (table 2) reflect the enantiomeric relationship and hence absolute configurations of 2S,3S,4R for (24) and 2R,3R,4S for (35) by application of the aromatic quadrant rule[6]. Notable in the cd spectra of both (24) and (35) is the low amplitude of the Cotton effect at 230 nm, contributed by the aryl chromophores at 4-C, which indicates the close proximity of the 4-C aryl substituent to the plane perpendicular to the D-ring through benzylic 4-C in conformations compatible with ^{1}H nmr coupling constants.

The hexamethyl ether acetates (26) and (37) of the all-trans-4-arylflavan-3-ols (25) and (36) exhibit coupling constants of heterocyclic protons ($J_{2,3}$ 5.5, $J_{3,4}$ 4.5 Hz) characteristic of 5-oxygenated analogues with a 4-C resorcinol-type substituent[5,6-10]. These conspicuously small J-values reflect significant contributions of A-conformers[11] thus reducing the dihedral angles of heterocyclic protons. Such a phenomenon most likely originates from repulsive interactions of 5-OMe(D) and 3-OAc(C) with the π-system of the resorcinol unit at 4-C in the corresponding E-conformers and may plausibly also explain the reversal of the sign of the Cotton effect at 239 nm i.e. positive and negative for (26) and (37) respectively vs. the anticipated negative and positive effects predicted by the

Table 1. ^{1}H Nmr peaks (ppm) of 4-arylflavan-3-ol hexamethyl ether acetates (22), (24), (29), and (31) at 300 MHz (23°C). Splitting patterns and J-values are given in parentheses.

Ring	Proton	(22) - C_6D_6	(24) - $CDCl_3$	(29)	(31)
A	3	7.01(d,8.5),5-H	6.49(d,2.5)	6.30(d,2.5)	6.07(d,2.5)
	5	6.63(dd,2.5,8.5),6-H	6.33(dd,2.5,8.5)	6.47(dd,2.5,8.5)	6.29(dd,2.5,8.5)
	6	6.87(d,2.5),8-H	6.62,(d,8.5)	7.46(d,8.5)	7.13(dd,1.0,8.5)
B	2	7.21(d,2.0)		6.86(d,2.0)	6.48(d,2.0)
	5	6.59(d,8.0)	6.75-6.77,6.87-6.89*	6.77(d,8.5)	6.44(d,8.5)
	6	7.00(dd,2.0,8.0)		6.64(dd,2.0,8.5)	6.33(dd,2.0,8.5)
C	2	5.20(br.s)	4.94(br.s)	5.29(br.s)	5.36(d,5.5)
	3	6.03(dd,1.0,5.0)	5.40(dd,1.0,2.0)	5.28(dd,1.0,2.0)	5.92(dd,4.5,5.5)
	4	5.51(d,5.0)	4.48(d,2.0)	4.27(d,2.0)	4.11(d,4.5)
D	5	6.07,6.15(each d,	6.11(d,2.5)	6.11(d,2.5)	6.08(d,2.5)
	7	2.0),3/5-H	6.27(d,2.5)	6.26(d,2.5)	6.30(d,2.5)
OMe		3.05(2/6-D),3.33 (4-B),3.36(7-A), 3.37(4D),3.41(x2), each s	3.59(5-D),3.78(4-A),3.82(7-D),3.83, 3.84,3.88(2-A), each s	3.48(2-A),3.62(5-D), 3.76(4-A),3.82(7-D), 3.84(3-B),3.85(4-B), each s	3.47(5-D),3.63(2-A), 3.67(4-A),3.70(3-B), 3.74(4-B),3.82(7-D), each s
OAc		1.54(s)	1.90(s)	1.87(s)	1.95(s)

*Second order

Table 2. Circular dichroism of 4-arylflavan-3-ols in methanol

Relative Configuration	Compound	λ/nm	[θ] x 10^4
2,3-cis-3,4-cis	(22)	280	+ 2.04
		265	- 7.30
		236	+22.43
	(33)	281	- 1.96
		264	+ 4.65
		237	- 5.36
2,3-cis-3,4-trans	(24)	263	+ 1.88
		240	+ 1.10
		230	- 0.33
	(29)	267	- 1.36
		242	- 1.94
		234	+ 9.71
	(35)	262	- 2.83
		241	- 2.34
		231	+ 0.56
	(39)	266	+ 1.62
		243	+ 1.76
		233	-14.41
2,3-trans-3,4-trans	(26)	284	+21.86
		265	+13.11
		240	+54.64
	(31)	283	+ 5.52
		265	+10.18
		241	- 5.87
	(37)	283	-10.89
		264	- 7.34
		241	-23.87
	(41)	284	- 4.65
		265	- 9.86
		243	+ 4.64

aromatic quadrant rule[6,12]. In phenol (25), the structure of which was confirmed by acid catalyzed coupling of (+)-leucocyanidin and resorcinol[7], heterocyclic coupling constants ($J_{2,3}$ 9.5, $J_{3,4}$ 8.0 Hz) and a negative Cotton effect at 235 nm are consistent with a predominant E-conformation of ring C. MM2 calculations[13]* indicate a preferred conformation about the 4-C —— resorcinol bond in which 4-H and 2-OH(A) are nearly eclipsed (17° deviation) to facilitate hydrogen bonding of 3-OH(C) with the π-system of the resorcinol moiety ultimately stabilizing the E-conformer. Collectively these data define the absolute configurations as 2R,3S,4R for (26) and 2S,3R,4S for (37).

Comparison of ^{1}H nmr data (table 1) of the 2,3-cis-3,4-trans derivatives (29) and (39) ($J_{2,3}$ ca 1.0, $J_{3,4}$ 2.0 Hz) with those of analogues (24) and (35) reveals the characteristic deshielding of 6-H(A) (Δδ-0.84) in the former pair associated with the 'interchange' of resorcinol A- and pyrocatechol B-rings[4,5]. The chemical shifts of 2- and 4-H(C) (δ5.29, 4.27 resp.) are unambiguously assigned by the nOe association (0.9%) between the latter proton and 5-OMe(D) (δ3.62). Location of the resorcinol and pyrocatechol moieties at 2- and 4-C respectively is confirmed by decoupling experiments demonstrating benzylic coupling of 2- and 4-H(C) to the o-proton(s) of the adjacent aryl rings. The nOe association of 2-H(C) and 2- and 6-H(B) confirms the 2,3-cis-3,4-trans relative configuration of both (29) and (39). A similar combination of ^{1}H nmr homonuclear decoupling and nOe techniques also facilitates structural elucidation of the 2,3-trans-3,4-trans-4-arylflavan-3-ols (31) and (41) ($J_{2,3}$ 5.5, $J_{3,4}$ 4.5 Hz). Assignment of absolute configuration of analogues (29), (31), (39), and (41) is discussed below.

The B-ring quinonemethide (20) serves as common precursor to the pyran-rearranged 4-arylflavan-3-ols derived from the (2R,3S,4R)-2,3-trans-3,4-cis analogue (11) (scheme 2). Whereas recyclization involving 2-OH(A) and the Si-face at 2-C in (20) leads to the 2,3-cis-3,4-cis homologue (21), pyran formation via stereoselective attack of 2-OH(D) at 2-C affords the 2,3-cis- and trans-3,4-trans-4-arylflavan-3-ols (23) and (25). Quinonemethide (20) is, however, subject to base catalyzed rearrangement to (27) via 1,3-migration of the phloroglucinol moiety to the Re-

*Details will be published elsewhere.

face at 2-C. Stereoselective pyran recyclization of quinonemethide (27) involving 2-OH(D) and both the Si- and Re-faces at 4-C then affords the cis-trans- and all-trans-isomers (28) and (30) having interchanged resorcinol A- and pyrocatechol B-rings compared to the positions of these units in analogues (23) and (25). Similar reasoning explains the genesis of isomers (32), (34), (36), (38), and (40) from the corresponding (2S,3R,4S)-4-arylflavan-3-ol (13) (scheme 2).

The generation of the ring-interchanged analogues (28), (30), (38), and (40) mechanistically requires inversion of the absolute configuration at 3-C relative to both those in their precursors (11) and (13) and of the 'normal' isomers, eg. (23) and (34). Such a phenomenon is unambiguously confirmed by comparison of the cd data (table 2) of the different enantiomeric- and quasi-enantiomeric pairs in scheme 2. The cis-trans isomers (29) and (39) exhibit positive and negative Cotton effects at 234 nm hence indicating 4β- and 4α-aryl substituents[6] for (29) and (39) respectively. When these data are interpreted in conjunction with ^{1}H nmr coupling constants of heterocyclic protons the absolute configuration of ring-interchanged analogues (29) and (39) may be defined as 2R,3R,4S for (29) and 2S,3S,4R for (39). These allocations are confirmed by comparison of the cd data of (29) and (39) with those of (35) and (24) respectively which unequivocally prove the quasi-enantiomeric relationship of these groups of compounds. In the all-trans pair (31) and (41) with interchanged A- and B-rings the signs of Cotton effects at ca. 240 nm are, like those of (26) and (37), opposite [negative for (31), positive for (41)] to those predicted by the aromatic quadrant rule[6]. Such a reversal is explicable in terms of predominance of A-conformers as was indicated above for (26) and (37). Cd data do, however, clearly show the quasi-enantiomeric relationship of (26) and (41), and of (31) and (37) hence facilitating establishment of 2S,3R,4S absolute configuration for (31) and 2R,3S,4R for (41).

Collectively the base catalyzed conversions of the 2,3-trans-3,4-cis-4-arylflavan-3-ols (11) and (13) as models for the fisetinidol-(+)-catechin biflavanoids[4,5], provide sufficient evidence for the inversion of absolute configuration at 3-C associated with the ring interchange. It furthermore furnishes the first explanation of the unusual chiroptical properties of some of the members of the all-trans analogues. Significant contributions of A-conformers, manifested in

reversal of the sign of the Cotton effect in the 220-240 nm region of cd spectra, are permitted only for those 4-C aryl substituents having at least one o-position unsubstituted. Such a conjecture explains the 'normal' Cotton effects of analogues with 4-C phloroglucinol-type substituents[6,7] and the conspicuous deviations associated with resorcinol- and pyrocatechol-type groups.

EXPERIMENTAL

^1H Nmr spectra were recorded on a Bruker AM-300 spectrometer in $CDCl_3$ or C_6D_6 with Me_4Si as internal standard. Mass spectral data were obtained with a Kratos MS80 instrument and cd data in methanol on a Jasco J-20 spectropolarimeter. Preparative plates (p.l.c.), 20x20 cm, Kieselgel PF_{254} (1.0 mm) were air-dried and used without prior activation. Column chromatography was on Sephadex LH-20 in ethanol. Methylations were performed with an excess of diazomethane in methanol-diethyl ether at -15°C for 48 h while acetylations were in acetic anhydride-pyridine for 8 h at ambient temperatures. Evaporations were done under reduced pressure at ca 60°C in a rotary evaporator.

The 4-(2,4,6-trihydroxyphenyl)-(10)-(13), and 4-(2,4-dihydroxyphenyl)flavan-3-ols (15) and (25) were prepared according to standard literature procedures[7].

Base catalyzed conversion of 4-arylflavan-3-ols. —— Owing to the enantiomeric relationship of (10) and (11) to (12) and (13), experimental detail is given for (10) and (11) only.

(2R,3S,4S)-4α-(2,4,6-Trihydroxyphenyl)flavan-3,3',4',7-tetraol (10).—— The 4-arylflavan-3-ol (10) (600 mg) was dissolved in 200 ml of a 0.025 M Na_2CO_3 - 0.025 M $NaHCO_3$ buffer (pH10) and the mixture was stirred under nitrogen at 50°C for 8 h. After chilling (0°C) and acidification (0.1 M HCl) the mixture was extracted with ethyl acetate (6x200 ml) and the solvent was removed to give a light-brown powder (550 mg). This was subjected to column chromatography (3x45 cm column, flow rate - 1.2 ml/min, 16 ml eluant/tube, first 75 ml of eluant discarded) using Sephadex LH-20/ethanol to give the following fractions: 1[tubes 11-15 (23 mg)], 2[36-49 (120 mg)], and 3[64-83 (98 mg)].

Fraction 1 consisted of catechinic acid-type products (cf. ref. 14) and will be reported elsewhere. Fraction 3 afforded unreacted starting material.

Methylation of fraction 2 (120 mg) followed by p.l.c. [hexane-benzene-acetone-methanol (40:40:15:5 v/v)] afforded a methyl ether band at R_F 0.51 (26 mg). Acetylation gave the 2,3-trans-3,4-cis-4-arylflavan-3-O-acetate (16) (29 mg) with physical data identical to those in the literature[7].

Identical treatment of the (2S,3R,4R)-enantiomer (12) afforded the hexamethyl ether acetate (19) of the (2S,3R,4R)-4α-(2,4-dihydroxyphenyl)flavan-3,3',4',5,7-pentaol (18) as a white powder (31 mg) (Found: M^+, 524.2052. $C_{29}H_{32}O_9$ requires M, 524.2046). ^1H Nmr data are identical and Cotton effects opposite to those of its enantiomer[7].

(2R,3S,4R)-4β-(2,4,6-Trihydroxyphenyl)flavan-3,3',4',7-tetraol (11). —— The 4-arylflavan-3-ol (11) (430 mg) was treated with 150 ml of the buffer solution at 50°C for 4 h. Work-up as above afforded a light-brown powder (350 mg) which was subjected to column chromatography (3x90 cm column, flow rate - 1 ml/min, first 600 ml of eluant discarded) using Sephadex LH-20/ethanol to give the following fractions: 1[tubes 25-48 (31 mg)], 2[58-62 (46 mg)], 3[63-71 (86 mg)], 4[72-74 (10 mg)], and 5[78-98 (150 mg)].

Fraction 1 consisted of catechinic acid-type products[14] and will be reported elsewhere. Fraction 2 afforded the starting 4-arylflavan-3-ol.

Methylation of fraction 2 (86 mg) and subsequent p.l.c. separation [benzene-acetone (9:1 v/v)] gave a single band (37 mg) at R_F 0.45. This was acetylated and the mixture resolved by p.l.c. [benzene-acetone (19:1 v/v)] to give two bands at R_F 0.45 (12 mg) and 0.33 (16.2 mg). The latter band consisted of the hexamethyl ether acetate of the starting material (11). The R_F 0.45 band afforded (2R,3R,4S)-3-acetoxy-2',4',5,7-tetramethoxy-4β-(3,4-dimethoxyphenyl)flavane (29) as white amorphous solid (Found: M^+, 524.2057. $C_{29}H_{32}O_9$ requires M, 524.2046); ^1H Nmr data (table 1); cd data (table 2).

Fraction 4 gave a pure sample of the 4-aryl-flavan-3-ol (28) with interchanged resorcinol and pyrocatechol rings.

A portion (110 mg) of fraction 5 was methylated and the mixture was resolved by p.l.c. [benzene-acetone (9:1 v/v)] to give two bands at R_F 0.49 (40 mg) and 0.40 (25 mg). Acetylation of the R_F 0.49 band and purification by p.l.c. [benzene-

acetone (19:1 v/v)] afforded a single fraction R_F 0.36 (30 mg) consisting of (2S,3S,4R)-3-acetoxy-3',4',7-trimethoxy-4β-(2,4,6-trimethoxyphenyl)flavan (22) as a white solid (Found: M^+, 524.2018. $C_{29}H_{32}O_9$ requires M, 524.2046); ^1H Nmr data (table 1); cd data (table 2). The R_F 0.40 band was resolved by p.l.c. [chloroform-hexane-acetone (85:16:4 v/v, x2)] into two bands at R_F 0.50 (4 mg) and 0.42 (16 mg). Acetylation of the R_F 0.50 band gave (2R,3S,4R)-3-acetoxy-3',4',5,7-tetramethoxy-4α-(2,4-dimethoxyphenyl)flavane (26) with physical data identical to those of an authentic sample[7]. Acetylation of the R_F 0.42 band and subsequent p.l.c. separation [benzene-acetone (19:1 v/v)] afforded two fractions at R_F 0.50 (11 mg) and 0.43 (1.5 mg). The R_F 0.50 band consisted of (2S,3S,4R)-3-acetoxy-3',4',5,7-tetramethoxy-4α-(2,4-dimethoxyphenyl)flavane (24) as a white solid (Found: M^+-HOAc, 464.1842. $C_{27}H_{28}O_7$ requires M-HOAc, 464.1835); ^1H Nmr data (table 1); cd data (table 2). The R_F 0.43 fraction afforded the (2S,3R,4S)-3-acetoxy-2',4',5,7-tetramethoxy-4β-(3,4-dimethoxyphenyl)flavan (31) as a white solid (Found: M^+, 524.2039. $C_{29}H_{32}O_9$ requires M, 524.2046); ^1H N.m.r. data (table 1); c.d. data (table 2).

Identical treatment of the (2S,3R,4S)-4-arylflavan-3-ol (13) affords the hexamethyl ether acetates (33), (35), (37), (39), and (41) enantiomerically related to those derived from (11). Their c.d. data are presented in table 2.

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REFERENCES

1. J.A. Steenkamp, J.P. Steynberg, E.V. Brandt, D. Ferreira, and D.G. Roux, J. Chem. Soc., Chem. Commun., 1985, 1678.
2. J.P. Steynberg, D.A. Young, J.F.W. Burger, D. Ferreira, and D.G. Roux, J. Chem. Soc., Chem. Commun., 1986, 1013.
3. J.P. Steynberg, J.F.W. Burger, D.A. Young, E.V. Brandt, J.A. Steenkamp, and D. Ferreira, J. Chem. Soc., Perkin Trans. 1, 1988, 8/00915E.
4. J.F.W. Burger, J.P. Steynberg, D.A. Young, E.V. Brandt, and D. Ferreira, J. Chem. Soc., Perkin Trans. 1, 1988, 8/02280A.
5. J.P. Steynberg. J.F.W. Burger, D.A. Young, E.V. Brandt, J.A. Steenkamp, and D. Ferreira, J. Chem. Soc., Chem. Commun., 1988, 8/00613J; J. Chem. Soc., Perkin Trans. 1, 1988, 8/00918J.
6. J.H. van der Westhuizen, D. Ferreira, and D.G. Roux, J. Chem. Soc., Perkin Trans. 1, 1981, 1220.
7. J.J. Botha, D. Ferreira, and D.G. Roux, J. Chem. Soc., Perkin Trans. 1, 1981, 1213.
8. J.W. Clark-Lewis, Aust. J. Chem., 1968, 21, 2059, and refs. cited therein.
9. A.C. Fletcher, L.J. Porter, E. Haslam, and R.K. Gupta, J. Chem. Soc., Perkin Trans. 1, 1977, 1628.
10. K. Weinges, H.D. Marx, and K. Göritz, Chem. Ber., 1970, 103, 2336.
11. L.J. Porter, R.Y. Wong, M. Benson, and B.G. Chan, J. Chem. Res. (M), 1986, 830.
12. G.G. DeAngelis and W.C. Wildman, Tetrahedron, 1969, 25,5099.
13. N.L. Allinger and Y.H. Yuh, Quantum Chemistry Program Exchange, 1980, 12, 395.
14. P.E. Laks, R.W. Hemingway, and A.H. Conner, J. Chem. Soc., Perkin Trans. 1, 1987, 1875.

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