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Tannins and Related Compounds. XC.[1] 8-*C*-Ascorbyl (−)-Epigallocatechin 3-*O*-Gallate and Novel Dimeric Flavan-3-ols, Oolonghomobisflavans A and B, from Oolong Tea. (3)

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A chemical examination of the polyphenolic constituents in commercial oolong tea has led to the isolation of a new-flavan-3-ol, two novel dimeric flavan-3-ols named oolonghomobisflavans A and B and eight new proanthocyanidins, together with twenty-one known polyphenols including proanthocyanidins, hydrolyzable tannins and red pigments. On the basis of chemical and spectroscopic evidence, the flavan-3-ol has been characterized as 8-*C*-ascorbyl (−)-epigallocatechin 3-*O*-gallate (22), while oolonghomobisflavans A (26) and B (27) have been determined to be dimeric flavan-3-ols in which two units are linked through a methylene bridge at the 8,8′- and 8,6′-positions, respectively. The structures of the new proanthocyanidins were elucidated mainly by tannase hydrolysis and thiolytic degradtion as epicatechin-(4β→8)-epigallocatechin 3-*O*-gallate (29), epicatechin 3-*O*-gallate-(4β→8)-epigallocatechin 3-*O*-gallate (30), catechin-(4α→8)-epigallocatechin 3-*O*-gallate (31), prodelphinidin B-4 3′-*O*-gallate (32), epicatechin 3-*O*-gallate-(4β→6)-epigallocatechin 3-*O*-gallate (33), epigallocatechin 3-*O*-gallate-(4β→6)-epicatechin 3-*O*-gallate (34), epiafzelechin 3-*O*-gallate-(4β→6)-epigallocatechin 3-*O*-gallate (35) and prodelphinidin B-2 3′-*O*-gallate (36).

Keywords oolong tea; polyphenol; 8-*C*-ascorbyl (−)-epigallocatechin 3-*O*-gallate; oolonghomobisflavan A; oolonghomobisflavan B; bisflavanoid; proanthocyanidin; tea catechin; flavan-3-ol; fermentation

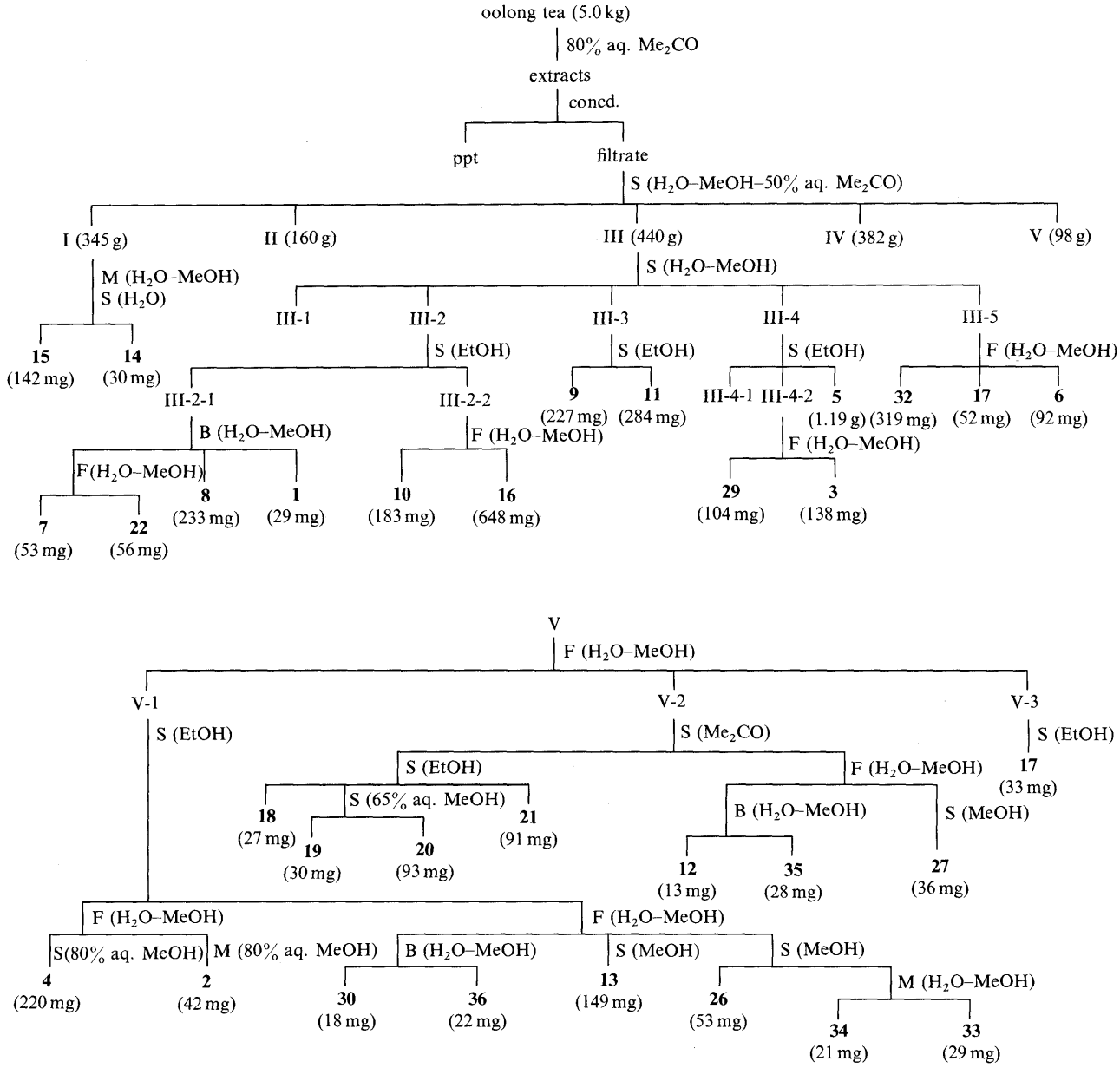
In order to clarify the mechanism of oxidation of tea leaf polyphenols in the fermentation process, we have been chemically examining the polyphenolic constituents in various beverage teas differing in the fermentation steps, and we previously demonstrated the occurrenc of a series of B,B′-ring linked dimeric flavan-3-ols (theasinensins) in green tea[3] and oolong tea[4] and of benzotropolone-type red pigments (theaflagallins) in back tea.[5] Furthermore, based on these structural studies, we proposed the possible enzymatic oxidation patterns of tea catechins during fermentation, and suggested that enzymatic oxidation invariably occurs at the B-ring of the flavan-3-ols.[4] The present paper describes further chemical examinations of oolong tea polyphenols, which led to the isolation and characterization of a new flavan-3-ol (**22**), two novel dimeric flavan-3-ols named oolonghomobisflavans A (**26**) and B (**27**), and proanthocyanidins (**29**—**36**), together with twenty-one previously known polyphenols including proanthocyanidins (**1**—**13**), hydrolyzable tannins (**14**—**16**) and red pigments (**17**—**21**).

Commercial oolong tea (commercial name; shiraore)[4] was extracted with 80% aqueous acetone, and the extract was repeatedly chromatographed over Sephadex LH-20 dextran and reversed-phase gels as shown in Chart 1 to yield thirty-two compounds (**1**—**22**, **26**, **27** and **29**—**36**). Among them, compounds **1**—**21** were found to be identical with procyanidin B-2 (**1**),[6] procyanidin B-2 3,3′-di-*O*-gallate (**2**),[3] epigallocatechin-(4β→8)-epicatechin 3-*O*-gallate (**3**),[6] epigallocatechin 3-*O*-gallate-(4β→8)-epicatechin 3-*O*-gallate (4),[7] epigallocatechin-(4β→8)-epigallocatechin 3-*O*-gallate[prodelphinidin B-2 3′-*O*-gallate] (**5**),[3] epigallocatechin 3-*O*-gallate-(4β→8)-epigallocatechin 3-*O*-gallate-[prodelphinidin B-2 3,3′-di-*O*-gallate] (**6**),[8] procyanidin B-3 (**7**),[9] procyanidin B-4 (**8**),[6] catechin-(4α→8)-epigallocatechin (**9**),[10] gallocatechin-(4α→8)-epicatechin (**10**),[10] gallocatechin-(4α→8)-epigallocatechin[prodelphinidin B-4] (**11**),[11] procyanidin B-5 3,3′-di-*O*-gallate (**12**),[12] epigallocatechin 3-*O*-gallate-(4β→6)-epigallocatechin 3-*O*-gallate-[prodelphinidin B-5 3,3′-di-*O*-gallate] (**13**),[8] theogallin (**14**),[13] β-glucogallin (**15**),[14] strictinin (**16**),[6] epitheaflagallin 3-*O*-gallate (**17**),[5] theaflavin (**18**),[15] theaflavin 3-*O*-gallate (**19**),[15] theaflavin 3′-*O*-gallate (**20**)[15] and theaflavin 3,3′-di-*O*-gallate (**21**),[15] respectively.

Compound **22** gave dark blue and orange colorations with the ferric chloride and anisaldehyde-sulfuric acid reagents, respectively, on thin-layer chromatography (TLC).

The ^{1}H-nuclear magnetic resonance (^{1}H-NMR) spectrum of **22** was closely related to that of (−)-epigallocatechin 3-*O*-gallate (**23**); in particular, the coupling patterns and chemical shifts of the signals from the B- and C-rings were almost identical. The observation of only one aromatic singlet (δ 6.05, 1H) arising from the flavan A-ring suggested the presence of a substituent at the C-6 or C-8 position. The ^{13}C-nuclear magnetic resonance (^{13}C-NMR) spectrum showed, besides galloyl and flavan signals, six signals due to a methylene (δ 62.9, t), two methines (δ 70.9, d; δ 83.7, d), an oxygen-bearing quaternary carbon (δ 79.5, s), a hemiacetal (δ 101.4, s) and a carboxyl carbon (δ 173.8, s). Taking the infrared (IR) absorption at 1775 cm^{-1} into account, the carboxyl resonance at δ 173.8 indicated the presence of a five-membered lactone ring.

Enzymatic hydrolysis of **22** with tannase yielded gallic acid and a hydrolysate (**22a**). On comparison of the ^{13}C-NMR spectra of **22** and **22a**, the significant upfield shift (−2.9 ppm) of the flavan C-3 signal in **22a** clearly indicated the location of the galloyl group at this position. Subsequent methylation of **22a** with dimethyl sulfate and potassium carbonate in dry acetone yielded the hexamethyl ether (**22b**) and an unexpected pentamethyl monoisopropylidene derivative (**22c**). The monoisopropylidene structure of **22c** was confirmed by derivation of **22c** from **22b** on treatment with *p*-toluenesulfonic acid in acetone. Thus, it is evident that a glycol system is present in **22**. On the other hand, the significant upfield shift of the lactone carbonyl signal in the ^{13}C-NMR spectrum of **22b** (Table I), which was considered to be caused by methylation of the neighboring hydroxyl group, indicated that the hydroxyl-bearing quaternary carbon is located next to the lactone carbonyl group. Furthermore, taking into account the presence of



S: Sephadex LH-20 M: MCI gel CHP20P F: Fuji gel ODS-G3 B: Bondapak C_{18} Porasil B

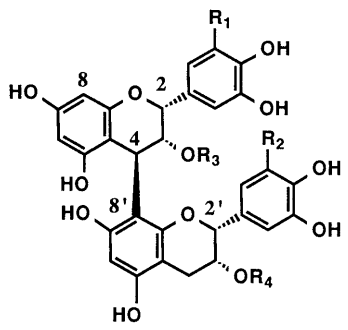
Chart 1

the above-mentioned hemiacetal and methine carbons, the A-ring substituent in **22** was considered to be derived from ascorbic acid. This was further confirmed by condensation of (−)-epigallocatechin (**23a**) and dehydroascorbic acid in the presence of sodium bicarbonate, which afforded a product found to be identical with **22a**.

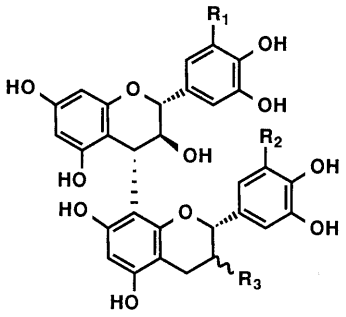
The location of the ascorbyl moiety in the A-ring was deduced by ^{13}C-NMR analysis of **22b**,[16] which showed signals due to the flavan C-6, C-4a and C-8 at δ 87.5, 101.1 and 113.5, respectively, the chemical shifts being in good agreement with those (C-6, δ 88.6; C-4a, δ 102.5; C-8, δ 112.2) in the C-8 substituted catechin derivative, gambiriin A-1 nonamethyl ether (**24**),[17] rather than the alternative C-6 substituted gambiriin A-3 nonamethyl ether (**25**)[17] (C-6, δ 117.7; C-4a, δ 105.4; C-8, δ 96.1). Thus the structure of this compound was determined to be as represented by the formula **22**. The absolute configurations of the quaternary and the hemiacetal carbons still remain to be solved.

Compounds **26** (oolonghomobisflavan A) and **27** (oolonghomobisflavan B) showed the same prominent $(M+H)^+$ ion peak at m/z 929 in the fast atom bombardment mass spectrum (FAB-MS).

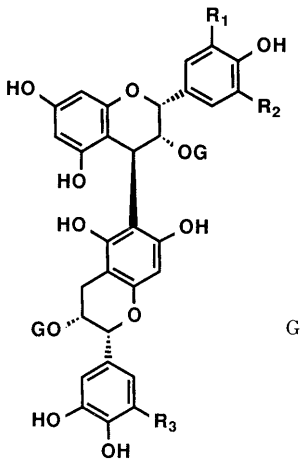
The ^{1}H-NMR spectrum of **27** indicated the presence of two epigallocatechin 3-*O*-gallate units in the molecule, each exhibiting signals due to the flavan B-rings (δ 6.64, 6.80, each 2H, s), C-rings (δ 5.52, 5.45: each 1H, m, H-3; δ 5.29, 5.00: each 1H, s, H-2; δ 2.76—3.20, 4H in total, H-4) and galloyl groups (δ 7.00, 7.09, each 2H, s). In addition, the appearance of only two singlets (δ 6.15, 6.18) attributable to the A-ring protons, as well as the presence of one benzylic methylene signal (δ 3.87, 2H, s), suggested the two flavan units to be connected through a methylene bridge at the respective C-6 and/or C-8 positions. The ^{1}H-NMR spectrum of **26**, on the other hand, showed the presence of



	R_1	R_2	R_3	R_4
1	H	H	H	H
2	H	H	G	G
3	OH	H	H	G
4	OH	H	G	G
5	OH	OH	H	G
6	OH	OH	G	G



	R_1	R_2	R_3
7	H	H	◀ OH
8	H	H	···ı OH
9	H	OH	···ı OH
10	OH	H	···ı OH
11	OH	OH	···ı OH



	R_1	R_2	R_3
12	H	OH	H
13	OH	OH	OH

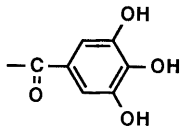
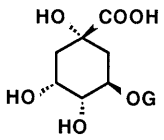
G: 

Chart 2



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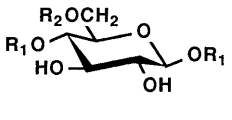
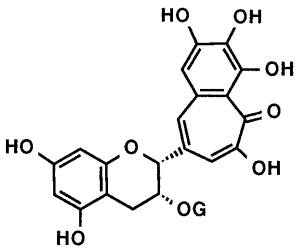


	R_1	R_2
15	H	H
16	(S)-HHDP	



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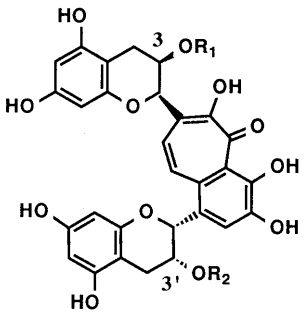


	R_1	R_2
18	H	H
19	G	H
20	H	G
21	G	G

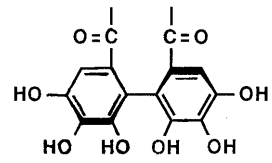
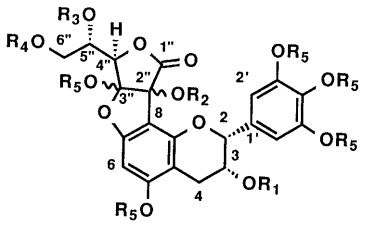
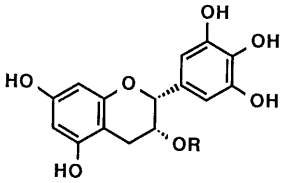
(S)-HHDP: 

Chart 3



	R_1	R_2	R_3	R_4	R_5
22	G	H	H	H	H
22a	H	H	H	H	H
22b	H	Me	H	H	Me
22c	H	H	CMe_2		Me
22d	H	Me	CMe_2		Me
22e	Ac	Ac	CMe_2		Me
22f	G	H	CMe_2		H
22g	Ac	Ac	Ac	Ac	Ac



23 : R=G
23a: R=H

Chart 4

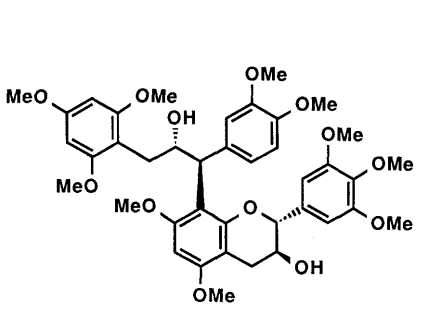
seemingly one epigallocatechin moiety. However, taking the above FAB-MS data into account, **26** is considered to possess a symmetrical dimeric flavan-3-ol structure.

TABLE I. ^{13}C-NMR Spectral Data for Compounds **22** and **22a**—**22g** (Ascorbyl Moiety)

	22[a]	**22a**[a]	**22b**[b]	**22c**[b]	**22d**[b]	**22e**[b]	**22f**[a]	**22g**[b]
C-1″	173.8	173.9	169.3	172.5	168.9	170.2[c]	173.8	170.5[c]
C-2″	79.5	79.5	84.0	79.1	84.3	82.1	79.1	82.6
C-3″	101.4	102.4	102.2	101.7	102.2	101.7	101.7	106.5
C-4″	83.4	83.4	83.0	82.7	85.2	82.1	86.2	83.4
C-5″	70.9	70.8	69.7	74.2	74.4	73.4	75.8	67.7
C-6″	62.9	62.8	62.8	65.3	65.5	66.2	66.0	62.6

a) Spectra were measured in acetone-d_6+D_2O at 25.05 MHz. *b*) Spectra were measured in $CDCl_3$ at 67.8 MHz. *c*) Signal may be interchanged with other carboxyl signals.

On enzymatic hydrolysis with tannase, **26** and **27** afforded the hydrolysates **26a** and **27a**, respectively, together with gallic acid. Subsequent treatment of **26a** and **27a** with diazomethane, followed by methylation with dimethyl sulfate and potassium carbonate,[18] yielded the corresponding decamethyl ethers **26b** and **27b**. The ^{13}C-NMR spectrum of **26b** showed signals due to flavan C-6, C-8 and C-4a at δ 89.3, 110.8 and 99.9, respectively, while those in **27b**



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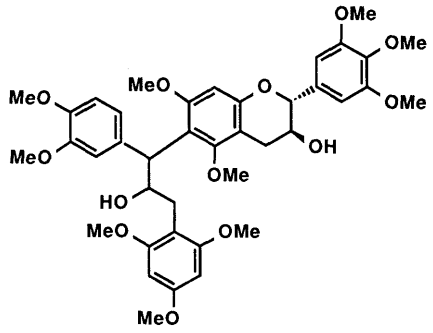

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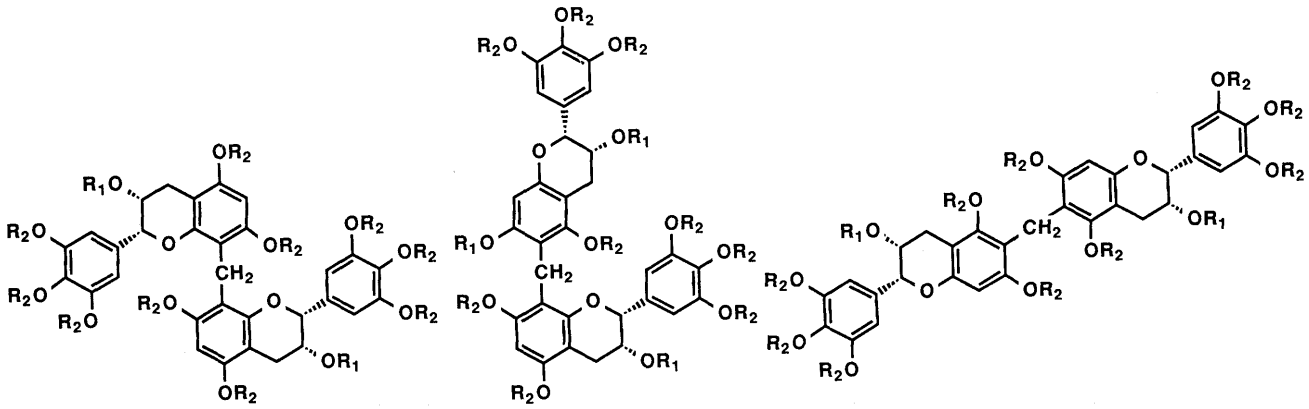
Chart 5



	R_1	R_2
26	G	H
26a	H	H
26b	H	Me

	R_1	R_2
27	G	H
27a	H	H
27b	H	Me

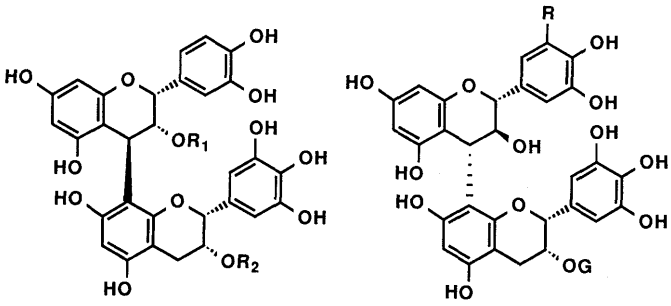
	R_1	R_2
28	G	H
28a	H	H
28b	H	Me

Chart 6

appeared at δ 89.3 (C-6), 117.1 (C-6), 110.6 (C-8), 96.2 (C-8), 100.2 (C-4a) and 104.6 (C-4a). The chemical shifts of the signals of **26b** were in good agreement with those found in the C-8 substituted catechin derivative (**24**). In contrast, the signal patterns in **27b** were consistent with the C-6 and C-8 substituted structure. Thus, the locations of the interflavanoid methylene were concluded to be at C-8, 8′ in **26b** and C-6, 8′ in **27b**.

To confirm unambiguously the structures of these compounds, attempts were made to prepare **26** and **27**. Condensation of **23** with formaldehyde in the presence of acid yielded three major products, among which two were found to be identical with **26** and **27** in respect of the specific optical rotations and the ^{1}H-NMR spectra. The remaining product was considered to be the 6,6′-linked 3-*O*-galloyl (−)-epigallocatechin dimer (**28**) from ^{1}H- and ^{13}C-NMR examinations. Thus, the structures of oolong-homobisflavans A and B wre represented by the formulae **26** and **27**, respectively.

Compounds **29**—**35** were found to be proanthocyanidins since they gave rise to reddish purple pigments on heating with acid. The presence of galloyl group(s) in each molecule was confirmed by the observation of the two-proton singlet signal(s) around δ 7.0—7.2 in the ^{1}H-NMR spectra. The dimeric constitutions of these compounds were deduced from the *Rf*-values on TLC and also from the appearance of two pairs of flavan H-2 and H-3 signals. Among these



	R_1	R_2
29	H	G
29a	H	H
30	G	G

31: R=H
32: R=OH

Chart 7

compounds, the structures of **29**—**32**, including the stereochemistry and the point of the interflavanoid linkage, were readily determined by tannase hydrolysis, which afforded the structurally known proanthocyanidins (**29a**[7] from **29** and **30**, **9** from **31** and **11** from **32**), together with gallic acid. The location of each galloyl group in compounds **29**—**32** was concluded on the basis of the respective acylation shifts observed in the ^{1}H-NMR spectra.

The structures of compounds **33**—**35** were established mainly by thiolytic degradation and ^{1}H-NMR examinations. Namely, acid treatment of **33** in the presence of

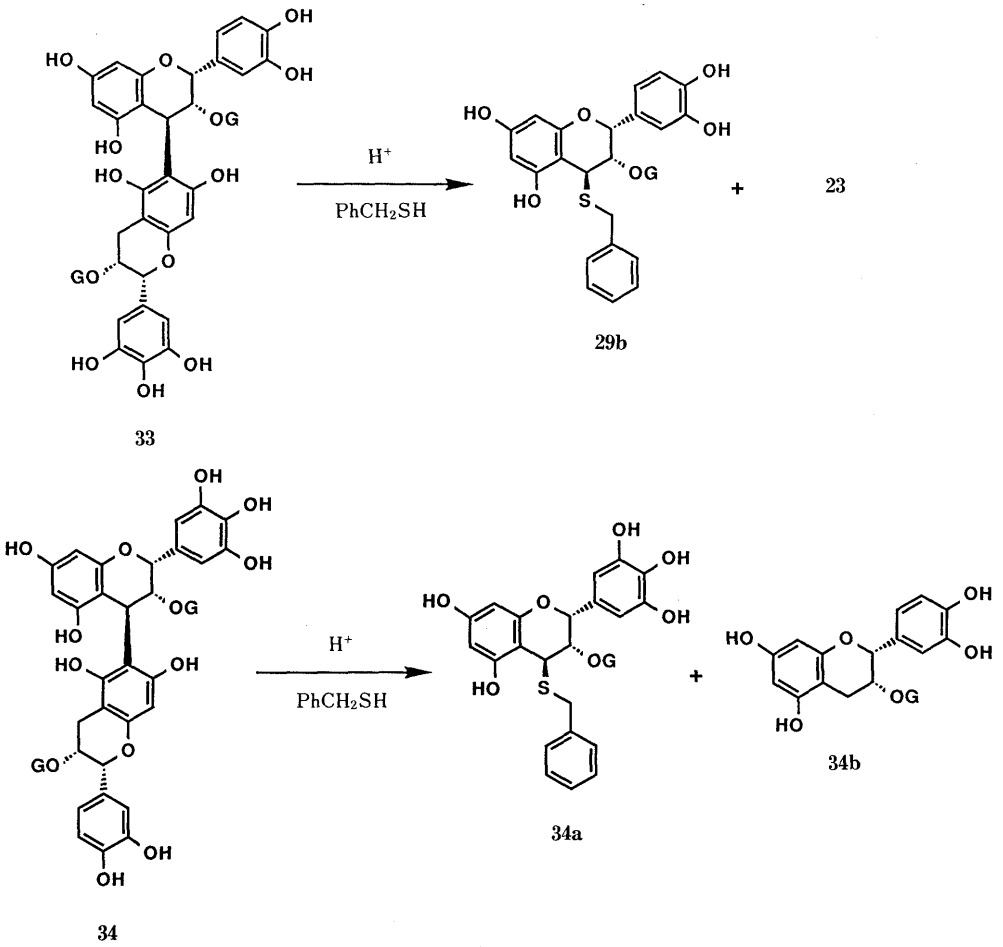


Chart 8

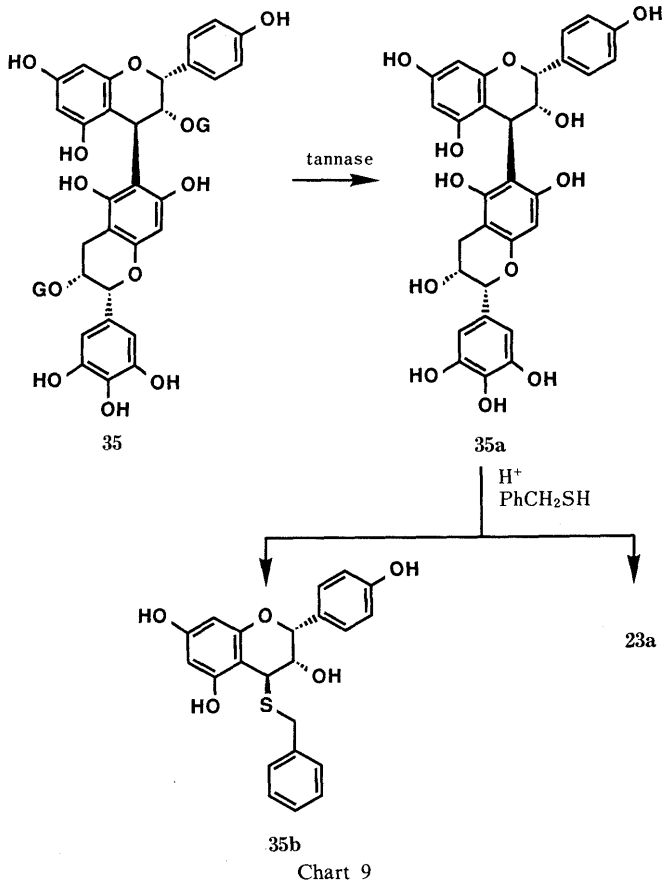


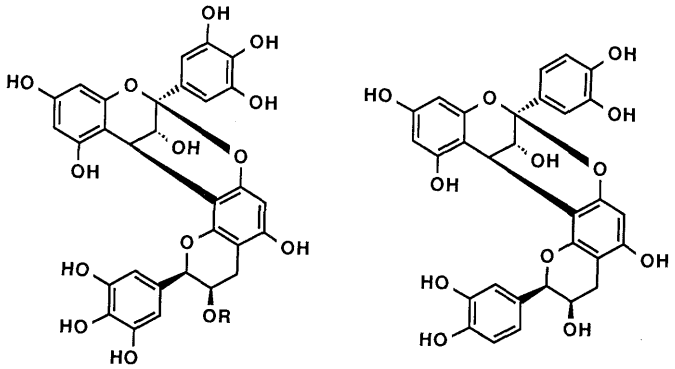
Chart 9

benzylmercaptan yielded 3-*O*-galloyl-(−)-epicatechin 4β-benzylthioether (**29b**) formed from the upper unit and (−)-epigallocatechin 3-*O*-gallate (**23**) from the lower half, while **34** afforded 3-*O*-galloyl-(−)-epigallocatechin 4β-benzylthioether (**34a**) and (−)-epicatechin 3-*O*-gallate (**34b**) (Chart 8). Furthermore, when the tannase hydrolysate (**35a**) of **35** was similarly degraded, (−)-epiafzelechin 4β-benzylthioether (**35b**) and (−)-epigallocatechin (**23a**) were formed. The interflavanoid linkage in these compounds was concluded to be at the C-4 and C-6 positions based on comparisons of the C-ring signal patterns in the ^{1}H-NMR spectra of **33**—**35** and **12**.

The ^{1}H-NMR spectrum of compound **36** showed two mutually coupled methine doublets at δ 4.16 (H-3) and 4.50 (H-4) (each J=4 Hz), typical of an intramolecularly doubly-linked proanthocyanidin.[19] The presence of a 3-*O*-galloyl epigallocatechin moiety in the lower unit was evident from the observation of a galloyl singlet at δ 7.17 (2H, s) and of signals arising from the flavan B-ring [δ 6.78 (2H, s)] and C-ring [δ 5.51 (1H, m, H-3), 5.15 (1H, s, H-2) and 2.82—3.20 (2H, m, H-4)].

Hydrolysis of **36** with tannase furnished gallic acid and the hydrolysate (**36a**), whose ^{1}H-NMR spectrum was almost identical with that of proanthocyanidin A-2 (**37**),[19] except for the appearance of two two-proton aromatic singlets at δ 6.78 and 6.81 instead of two ABX-type signals.

Final structural confirmation was obtained by oxidation of **3** with hydrogen peroxide in a weakly alkaline medium to give **36**.[19] Thus, **36** was characterized as prodelphinidin A-



36 : R=G
36a: R=H

37

Chart 10

2 3′-*O*-gallate.

Oolonghomobisflavans A (**26**) and B (**27**) isolated in this study, are the first bisflavanoids linked at the A,A′-rings through a methylene bridge. Although we have not yet ascertained whether **23** and **27** occur in the original fresh tea leaf or are produced by enzymatic oxidation during fermentation, it is of great interest from the view point of both the chemotaxonomy of tea plants and the activity of the endogenous polyphenol oxidase in tea leaf that **26** and **27** are only isolable from oolong tea and not from green tea or black tea.

Experimental

Details of the instruments and chromatographic conditions used in this study are essentially the same as described in the previous paper.[3]

Isolation Fractions I, III and V, previously obtained from the 80% aqueous acetone extract of commercial oolong tea (commercial name: shiraore),[4] were separated as shown in Chart 1 to furnish compounds **1**—**22**, **26**, **27** and **29**—**36**, of which **1**—**21** were identified as structually known polyphenols as described in the text.

8-C-Ascorbyl (−)-Epigallocatechin 3-*O*-Gallate (22) An off-white amorphous powder, $[\alpha]_D^{21}$ −215.1° (*c*=1.0, acetone). *Anal.* Calcd for $C_{28}H_{24}O_{17}\cdot 1/2H_2O$: C, 52.42; H, 3.92. Found: C, 52.37; H, 4.28. Negative FAB-MS *m/z*: 631 $(M-H)^-$. IR ν_{max}^{KBr} cm^{-1}: 3300 (OH) 1775 (C=O), 1620 (arom C=C). ^{1}H-NMR (acetone-d_6): 3.05 (2H, m, 4-H), 3.68—3.96 (2H, m, 6″-H), 4.22 (1H, dd, *J*=10.4 Hz, 5″-H), 4.53 (1H, d, *J*=4 Hz, 4″-H), 5.16 (1H, br s, 2-H), 5.50 (1H, m, 3-H), 6.05 (1H, s, 6-H), 6.77 (2H, s, 2′, 6′-H), 7.00 (2H, s, galloyl H). ^{13}C-NMR (acetone-d_6): 26.5 (C-4), 62.9 (C-6″), 69.5 (C-3), 70.9 (C-5″), 78.1 (C-2), 79.5 (C-2″), 83.7 (C-4″), 91.3 (C-6), 101.4 (C-3″), 102.7 (C-4a), 106.6 (C-2′,6′), 110.1 (galloyl C-2,6), 111.8 (C-8), 121.5 (galloyl C-1), 130.2 (C-1′), 132.8 (C-4′), 138.8 (galloyl C-4), 145.7, 146.0 (C-3, 5, galloyl C-3, 5), 154.4, 158.4, 160.2 (C-5, 7, 8a), 166.3 (COO), 173.8 (CO).

Tannase Hydrolysis of 22 A solution of **22** (70 mg) in H_2O (5 ml) was shaken with tannase at room temperature for 10 min. The reaction mixture was directly applied to an MCI-gel CHP-20P column. Elution with H_2O, containing increasing amounts of MeOH, gave gallic acid and **22a** (43 mg) as an off-white amorphous powder, $[\alpha]_D^{25}$ −109.7° (*c*=1.1, acetone). *Anal.* Calcd for $C_{21}H_{20}O_{13}\cdot 5/2H_2O$: C, 48.00; H, 4.80. Found: C, 48.21; H, 4.87. Negative FAB-MS *m/z*: 479 $(M-H)^-$. IR ν_{max}^{KBr} cm^{-1}: 3330 (OH), 1777 (CO), 1620 (arom C=C). ^{1}H-NMR (acetone-d_6+D_2O): 2.83 (2H, m, 4-H), 3.76 (2H, m, 6″-H), 4.15 (1H, m, 5″-H), 4.28 (1H, m, 3-H), 4.38 (1H, d, *J*=5 Hz, 4″-H), 4.92 (1H, br s, 2-H), 6.08 (1H, s, 6-H), 6.67 (2H, s, 2′,6′-H). ^{13}C-NMR (acetone-d_6+D_2O): 29.1 (C-4), 62.8 (C-6″), 66.6 (C-3), 70.8 (C-5″), 79.2 (C-2), 79.5 (C-2″), 83.4 (C-4″), 91.1 (C-6), 102.4 (C-4a, C-3″), 106.2 (C-2′, 6′), 111.8 (C-8), 130.8 (C-1′), 132.7 (C-4′), 146.1 (C-3′,5′), 154.6, 158.1, 160.6 (C-5, 7, 8a), 173.9 (C-1″).

Acetylation of 22a A solution of **22a** (18 mg) in dry pyridine (2 ml) and acetic anhydride (1 ml) was kept at room temperature for 17 h. Excess reagent was decomposed by addition of ice-water, and the resulting precipitates were collected by filtration. Purification by silica gel chromatography with benzene–acetone (4:1, v/v) yielded the nonaacetate (**22g**) (25 mg) as an off-white amorphous powder, $[\alpha]_D^{22}$ −96.1° (*c*=1.0, $CHCl_3$). *Anal.* Calcd for $C_{39}H_{38}O_{22}$: C, 54.55; H, 4.46. Found: C, 54.34; H, 4.55. FD-MS *m/z*: 858 $(M)^+$. ^{1}H-NMR ($CDCl_3$): 1.83, 2.09, 2.10, 2.11, 2.18, 2.28(×2), 2.29, 2.30 (each 3H, s, $COCH_3$), 2.65—2.82 (2H, m, 4-H), 4.28 (1H, dd, *J*=11, 6 Hz, 6″-H), 5.02 (1H, d, *J*=4 Hz, 4″-H), 5.21 (1H, br s, 2-H), 5.45 (1H, m, 3-H), 5.68 (1H, ddd, *J*=6, 5, 4 Hz, 5″-H), 6.40 (1H, s, 6-H), 7.42 (2H, s, 2′, 6′-H). ^{13}C-NMR ($CDCl_3$): 20.2, 20.5, 20.6, 20.7, 20.8, 20.9, 21.0 (9×$COCH_3$), 25.9 (C-4), 62.6 (C-6″), 66.0 (C-3), 67.7 (C-5″), 76.7 (C-2), 82.6 (C-2″), 83.4 (C-4″), 98.3 (C-6), 104.0 (C-4a), 106.5 (C-3″), 109.8 (C-8), 118.8 (C-2′, 6′), 131.4 (C-1′), 135.1 (C-4′), 143.3 (C-3′, 5′), 151.9, 153.0 156.4 (C-5, 7, 8a), 165.8, 166.6, 167.0, 168.1, 168.6, 169.7, 170.3, 170.5 (C-1″, 9×CO).

Methylation of 22a A mixture of **22a** (1.5 g), Me_2SO_4 (3 ml) and anhydrous K_2CO_3 (5 g) in dry acetone (50 ml) was refluxed for 6 h with stirring. After removal of inorganic salts by filtration, the filtrate was concentrated to a syrup, which was chromatographed over silica gel. Elution with benzene–acetone (9:1—2:1, v/v) gave the hexamethyl ether (**22b**) (248 mg) and the crude pentamethyl monoisopropylidene (**22c**), the latter of which was further purified by silica gel chromatography with benzene–ethyl acetate (5:2, v/v) to yield pure **22c** (140 mg). **22b**: an off-white amorphous powder, $[\alpha]_D^{22}$ −62.1° (*c*=1.5, $CHCl_3$). *Anal.* Calcd for $C_{27}H_{32}O_{13}\cdot 1/2H_2O$: C, 56.54; H, 5.80. Found: C, 56.74; H, 5.80. EI-MS *m/z*: 564 $(M)^+$. ^{1}H-NMR ($CDCl_3$): 2.81 (1H, dd, *J*=16, 4 Hz, 4-H), 3.06 (1H, dd, *J*=16, 2 Hz, 4-H), 3.65, 3.67, 3.85, 3.87, 3.95 (×2) (each 3H, s, OCH_3), 3.65—3.95 (2H, m, 6″-H), 4.24 (1H, m, 5″-H), 4.34 (1H, m, 3-H), 4.36 (1H, d, *J*=4 Hz, 4″-H), 5.11 (1H, br s, 2-H), 6.17 (1H, s, 6-H), 6.92 (2H, s, 2′,6′-H). ^{13}C-NMR ($CDCl_3$): 27.5 (C-4), 53.3, 55.9, 56.4, 56.5(×2), 60.8 (OCH_3), 62.8 (C-6″), 66.1 (C-3), 69.7 (C-5″), 78.4 (C-2), 83.0 (C-4″), 84.0 (C-2″), 87.5 (C-6), 101.1 (C-4a), 102.2 (C-3″), 102.7 (C-2′, 6′), 113.5 (C-8), 133.0 (C-1′), 137.4 (C-4′), 152.4, 158.0, 162.4 (C-5, 7, 8a), 153.8 (C-3′, 5′), 169.3 (C-1″). **22c**: an off-white amorphous powder, $[\alpha]_D^{22}$ −59.4° (*c*=1.0, $CHCl_3$). *Anal.* Calcd for $C_{29}H_{34}H_{13}\cdot 1/2H_2O$: C, 58.09; H, 5.88. Found: C, 58.25; H, 5.87. ^{1}H-NMR ($CDCl_3$): 1.40, 1.42 (each 3H, s, CH_3), 2.75 (1H, dd, *J*=18, 4 Hz, 4-H), 3.09 (1H, dd, *J*=18, 2 Hz, 4-H), 3.57, 3.81, 3.85, 3.92 (×2) (each 3H, s, OCH_3), 4.18 (2H, m, 6″-H), 4.22 (1H, m, 3-H), 4.50 (2H, m, 4″, 5″-H), 5.19 (1H, br s, 2-H), 6.13 (1H, s, 6-H), 6.96 (2H, s, 2′, 6′-H). ^{13}C-NMR ($CDCl_3$): 25.3, 25.4 (CH_3), 27.0 (C-4), 52.6, 55.8, 56.3 (×2), 60.8 (OCH_3), 65.3 (C-6″), 66.0 (C-3), 74.2 (C-5″), 78.4 (C-2), 79.1 (C-4″), 82.3 (C-2″), 86.7 (C-6), 101.7 (C-3″), 102.3 (C-4a), 102.9 (C-2′, 6′), 110.9 (O_2CMe_2), 112.4 (C-8), 133.3 (C-1′), 137.5 (C-4′), 151.8 (C-5, 7, 8a), 153.8 (C-3′, 5′), 172.5 (C-1″).

Acetylation of 22c A solution of **22c** (20 mg) in dry pyridine (2 ml) and acetic anhydride (1 ml) was kept at room temperature for 12 h. Excess reagent was decomposed by addition of ice-water, and the resulting precipitates were collected by filtration. Purification by silica gel chromatography with benzene–ethyl acetate (9:1—1:1, v/v) yielded the diacetate (**22e**) (16 mg) as an off-white amorphous powder, $[\alpha]_D^{22}$ −61.8° (*c*=1.8, $CHCl_3$). *Anal.* Calcd for $C_{33}H_{38}O_{15}$: C, 58.75; H, 5.68. Found: C, 58.30; H, 5.75. EI-MS *m/z*: 674 $(M)^+$. ^{1}H-NMR ($CDCl_3$): 1.38, 1.47 (each 3H, s, CH_3), 1.81, 2.12 (each 3H, s, $COCH_3$), 2.93 (2H, m, 4-H), 3.45, 3.84, 3.86, 3.89 (×2) (each 3H, s, OCH_3), 4.13 (1H, d, *J*=6 Hz, 4″-H), 4.22 (1H, m, 5″-H), 4.59 (2H, m, 6″-H), 5.17 (1H, br s, 2-H), 5.53 (1H, m, 3-H), 6.14 (1H, s, 6-H), 6.92 (2H, s, 2′, 6′-H). ^{13}C-NMR ($CDCl_3$): 20.2, 20.8 ($COCH_3$), 24.8, 26.8 (CH_3), 25.6 (C-4), 52.4, 55.9, 56.4 (×2), 60.8 (OCH_3), 66.2, 66.8 (C-3, 6″), 73.4 (C-5″), 77.3 (C-2), 82.1 (C-2″), 86.4 (C-4″), 88.2 (C-6), 98.5 (C-4a), 101.7 (C-3″), 103.2 (C-2′, 6′), 109.5 (O_2CMe_2), 112.1 (C-8), 132.9 (C-1′), 137.1 (C-4′), 152.5, 157.7, 162.4 (C-5, 7, 8a), 153.1 (C-3′, 5′), 166.5, 169.1, 170.2 (C-1″, 2×CO).

Preparation of 22c and 22d from 22b A solution of **22b** (80 mg) in dry acetone (10 ml) containing *p*-TsOH (10 mg) was allowed to stand for 1 h. The reaction mixture was concentrated to a syrup, which was chromatographed over silica gel. Elution with benzene–acetone (9:1, v/v) gave the pentamethyl monoisopropylidene derivative (**22c**) (10 mg) and the hexamethyl monoisopropylidene derivative (**22d**) as an off-white amorphous powder, $[\alpha]_D^{22}$ −88.7° (*c*=0.6, $CHCl_3$). *Anal.* Calcd for $C_{30}H_{36}O_{13}$: C, 59.59; H, 6,00. Found: C, 59.34; H, 6.06. EI-MS *m/z*: 604 $(M)^+$. ^{1}H-NMR ($CDCl_3$): 1.38, 1.44 (each 3H, s, CH_3), 2.81 (1H, dd, *J*=18, 4 Hz, 4-H), 3.08 (1H, dd, *J*=18, 2 Hz, 4-H), 3.59, 3.66, 3.84, 3.87, 3.95 (×2) (each 3H, s, OCH_3), 4.10 (1H, d, *J*=8 Hz, 5″-H), 4.20 (1H, s, 4″-H), 4.32, 4.46 (each 1H, d, *J*=8 Hz, 6″-H), 4.34 (1H, m, 3-H), 5.11 (1H, br s, 2-H), 6.18 (1H, s, 6-H), 6.90 (2H, s, 2′, 6′-H). ^{13}C-NMR ($CDCl_3$): 24.9, 26.5 (CH_3), 27.5 (C-4), 53.2, 55.0, 55.9, 56.5 (×2), 60.7 (OCH_3), 65.5 (C-6″), 66.1 (C-3), 74.4 (C-5″), 78.3 (C-2), 84.3 (C-2″), 85.2 (C-4″), 87.6 (C-6), 100.9 (C-4a), 102.2 (C-3″), 102.7 (C-2′, 6′), 109.9 (O_2CMe_2), 112.7 (C-8), 133.0 (C-1′), 137.4 (C-4′), 152.6, 157.4, 162.5 (C-5, 7, 8a), 153.7 (C-3′, 5′), 168.9 (C-1″).

Preparation of 22f from 22 A solution of **22** (70 mg) in dry acetone

(10 ml) containing *p*-TsOH (5 mg) was allowed to stand for 1 h. The reaction mixture was concentrated and subjected to Sephadex LH-20 column chromatography. Elution with acetone–H_2O (1:0—9:1, v/v) gave the monoisopropylidene derivative (**22f**) as an off-white amorphous powder, $[\alpha]_D^{20}$ −201.9 (c=0.9, acetone). *Anal.* Calcd for $C_{31}H_{28}O_{17}\cdot 3H_2O$: C, 51.24; H, 4.71. Found: C, 51.48; H, 4.50. Negative FAB-MS m/z: 671 $(M-H)^-$. ^{1}H-NMR (acetone-d_6 + D_2O): 1.68, 1.38 (each 3H, s, CH_3), 3.03 (2H, m, 4-H), 4.06, 4.30 (each 1H, dd, J=10, 6 Hz, 6″-H), 4.29 (1H, d, J=6 Hz, 4″-H), 4.47 (1H, m, J=6 Hz, 5″-H), 5.15 (1H, br s, 2-H), 5.45 (1H, m, 3-H), 6.09 (1H, s, 6-H), 6.86 (2H, s, 2′, 6′-H), 6.99 (2H, s, galloyl-H). ^{13}C-NMR (acetone-d_6 + D_2O): 25.3, 26.7, 26.8 (C-4, 2 × CH_3), 66.0 (C-6″), 69.7 (C-3), 75.8 (C-5″), 78.2 (C-2), 79.1 (C-2″), 86.2 (C-4″), 91.4 (C-6), 101.7 (C-3″), 102.7 (C-4a), 106.3 (C-2′, 6′), 110.0 (galloyl C-2, 6), 110.4 (O_2CMe_2), 111.4 (C-8), 121.5 (galloyl C-1), 130.1 (C-1′), 132.9 (C-4′), 138.9 (galloyl C-4), 145.8, 146.1 (C-3′, 5′, galloyl C-3, 5), 154.6, 158.1, 160.8 (C-5, 7, 8a), 166.4 (COO), 173.8 (C-1″).

Preparation of 22a A solution of L-dehydroascorbic acid (5 g) and (−)-epigallocatechin (**23a**) (8 g) in 1% $NaHCO_3$–H_2O (50 ml) was stirred for 3 h at room temperature. The reaction mixture was directly applied to a column of MCI-gel CHP-20P. Elution with H_2O containing increasing amounts of MeOH gave the crude product, which was purified by Sephadex LH-20 and Bondapak C_{18} Porasil B chromatographies with H_2O–MeOH to afford **22a** (2.3 g).

Oolonghomobisflavan A (26) A tan amorphous powder, $[\alpha]_D^{26}$ −271.0° (c=1.0, acetone). *Anal.* Calcd for $C_{45}H_{36}O_{22}\cdot 4H_2O$: C, 54.00; H, 4.43. Found: C, 54.09; H, 4.31. FAB-MS m/z: 929 $(M+H)^+$. ^{1}H-NMR (acetone-d_6): 2.80—3.20 (4H, m, 4-H), 4.01 (2H, br s, $-CH_2-$), 5.12 (2H, s, 2-H), 5.63 (2H, m, 3-H), 6.10 (2H, s, 6-H), 6.76 (4H, s, 2′, 6′-H), 7.09 (4H, s, galloyl-H). ^{13}C-NMR (acetone-d_6 + D_2O): 16.2 ($-CH_2-$), 26.9 (C-4), 69.4 (C-3), 79.4 (C-2), 97.5, 99.4 (C-4a, 6), 105.4 (C-8), 106.8 (C-2′, 6′), 110.3 (galloyl C-2, 6), 121.1 (galloyl C-1), 129.6 (C-1′), 133.5 (C-4′), 139.2 (galloyl C-4), 145.8, 146.4 (C-3′, 5′, galloyl C-3, 5), 152.5, 155.3, 155.7 (C-5, 7, 8a), 166.7 (COO).

Oolonghomobisflavan B (24) A tan amorphous powder, $[\alpha]_D^{26}$ −205.0° (c=1.0, acetone). *Anal.* Calcd for $C_{45}H_{36}O_{22}\cdot 3H_2O$: C, 54.99, H, 4.31. Found: C, 55.24; H, 4.48. FAB-MS m/z: 929 $(M+H)^+$. ^{1}H-NMR (acetone-d_6): 2.76—3.20 (4H, m, 4, 4′-H), 4.70 (2H, br s, $-CH_2-$), 5.00 (1H, s, 2′-H), 5.29 (1H, s, 2-H), 5.45 (1H, m, 3′-H), 5.52 (1H, m, 3-H), 6.15, 6.18 (ech 1H, s, 6, 8′-H), 6.64, 6.80 (each 2H, s, B, B′-ring-H), 7.00, 7.09 (each 2H, s, galloyl-H). ^{13}C-NMR (acetone-d_6 + D_2O): 17.1 ($-CH_2-$), 26.6, 27.0 (C-4, 4′), 69.4, 69.8 (C-3, 3′), 78.0, 79.6 (C-2, 2′), 96.5, 97.3 (C-6, 8′), 99.7, 100.3 (C-4a, 4′a), 105.9, 107.5 (C-8′, 6), 106.6 (B, B′-ring C-2, 6), 110.0 (2 × galloyl C-2, 6), 121.3, 121.5 (galloyl C-1), 129.4, 130.6 (B, B′-ring C-1), 133.1, 133.5 (B, B′-ring C-4), 138.1 (2 × galloyl C-4), 145.9, 146.2, 146.6 (B, B′-ring C-3,5, 2 × galloyl C-3, 5), 152.5, 154.2, 154.9, 155.7 (C-5, 7, 8a, 5′, 7′, 8′a), 166.4, 166.6 (COO).

Tannase Hydrolysis of 26 A solution of **26** (28 mg) in H_2O (5 ml) was treated with tannase at room temperature for 10 min. Work-up as described above gave gallic acid and **26a** (8 mg) as colorless needles, mp 235—238 °C, $[\alpha]_D^{21}$ −161.1° (c=0.8, acetone). *Anal.* Calcd for $C_{31}H_{28}O_{14}\cdot 2H_2O$: C, 56.36; H, 4.88. Found: C, 56.00; H, 4.86. ^{1}H-NMR (acetone-d_6 + D_2O): 2.64—3.05 (4H, m, 4-H), 3.83 (2H, br s, $-CH_2-$), 4.24 (2H, m, 3-H), 4.96 (2H, s, 2-H), 5.99 (2H, s, 6-H), 6.70 (4H, s, 2′, 6′-H). ^{13}C-NMR (acetone-d_6 + D_2O): 16.3 ($-CH_2-$), 28.9 (C-4), 66.4 (C-3), 80.4 (C-2), 96.9 (C-6), 100.0 (C-4a), 105.3 (C-8), 106.8 (C-2′, 6′), 130.3 (C-1′), 133.0 (C-4′), 146.1 (C-3′, 5′), 155.0, 155.2, 155.5 (C-5, 7, 8a).

Methylation of 26a A solution of **26a** (155 mg) in MeOH (10 ml) was treated with ethereal diazomethane at room temperature for 12 h. After evaporation of the solvent, the residue was chromatographed over silica gel with benzene–acetone (4:1, v/v) to yield a methylation product mixture (11 mg), which was further methylated with Me_2SO_4 (0.1 ml) and anhydrous K_2CO_3 (0.1 g) in dry acetone (2 ml) under reflux for 1 h. After removal of inorganic salts by filtration, the filtrate was concentrated to a syrup, which was chromatographed over silica gel. Elution with benzene–ethyl acetate (2:3, v/v) gave a decamethyl ether (**26a**) (11 mg) as an off-white amorphous powder, $[\alpha]_D^{22}$ −7.7° (c=1.0, $CHCl_3$). *Anal.* Calcd for $C_{41}H_{48}O_{14}$: C, 64.38; H, 6.33. Found: C, 64.55; H, 6.59. ^{1}H-NMR ($CDCl_3$): 2.68—3.10 (4H, m, 4-H), 3.61 (6H, s, 2 × OCH_3), 3.72—3.92 (24H in total, m, 8 × OCH_3), 4.04 (2H, br s, $-CH_2-$), 4.19 (2H, m, 3-H), 4.59 (2H, s, 2-H), 6.07 (2H, s, 6-H), 6.67 (4H, s, 2′, 6′-H). ^{13}C-NMR ($CDCl_3$): 16.9 ($-CH_2-$), 38.6 (C-4), 55.3, 56.0, 56.4, 60.8 (OCH_3), 66.3 (C-3), 78.2 (C-2), 89.3 (C-6), 99.9 (C-4a), 103.5 (C-2′, 6′), 110.8 (C-8), 134.7 (C-1′), 137.4 (C-4′), 153.2 (C-3′, 5′), 152.9, 156.4, 157.7 (C-5, 7, 8a).

Tannase Hydrolysis of 27 A solution of **27** (17 mg) in H_2O (5 ml) was treated with tannase at room temperature for 10 min. Work-up as described above gave gallic acid and **27a** (7 mg) as an off-white amorphous powder, $[\alpha]_D^{21}$ −114.6° (c=0.7, acetone). *Anal.* Calcd for $C_{31}H_{28}O_{14}\cdot 5/2H_2O$: C, 55.60; H, 4.97. Found: C, 55.41; H, 4.86. ^{1}H-NMR (acetone-d_6 + D_2O): 2.50—3.10 (4H, m, 4, 4′-H), 3.77 (2H, br s, $-CH_2-$), 4.13 (2H, m, 3′-H), 4.27 (1H, m, 3-H), 4.75 (1H, s, 2′-H), 5.03 (1H, s, 2-H), 5.98 (1H, s, 6-H), 6.15 (1H, s, 8′-H), 6.53 (2H, s, B′-ring-H), 6,72 (2H, s, B-ring-H). ^{13}C-NMR (acetone-d_6 + D_2O): 17.1 ($-CH_2-$), 28.4, 29.2 (C-4, 4′), 66.3, 66.8 (C-3, 3′), 79.1, 80.7 (C-2, 2′), 96.2, 97.1 (C-6, 8′), 100.6, 101.1 (C-4a, 4′a), 105.9 (C-8′), 106.8, 107.1 (B, B′-ring C-2, 6), 107.2 (C-6), 130.1, 131.1 (B, B-ring C-1), 132.8, 133.3 (B, B′-ring C-4), 146.0, 146.2 (B, B′-ring C-3,5), 152.5, 153.7, 154.0, 155.6 (C-5, 7, 8a, 5′, 7′, 8′a).

Methylation of 27a A solution of **27a** (62 mg) in MeOH (10 ml) was treated with ethereal diazomethane at room temperature for 12 h. After evaporation of the solvent, the residue was subjected to silica gel chromatography with benzene–acetone (3:1, v/v). The incomplete methylation products (12 mg) thus obtained were further methylated with Me_2SO_4 (0.1 ml) and anhydrous K_2CO_3 (0.1 g) in dry acetone (2 ml) under reflux for 1 h. The reaction mixture was worked up as described for **26a** to give a decamethyl ether (**27b**) (10 mg) as an off-white amorphous powder, $[\alpha]_D^{22}$ −1.1° (c=0.8, $CHCl_3$). *Anal.* Calcd for $C_{41}H_{48}O_{14}\cdot 1/8H_2O$: C, 64.20; H, 6.57. Found: C, 64.68; H, 6.98. ^{1}H-NMR ($CDCl_3$): 2.70—3.20 (4H, m, 4, 4′-H), 3.51, 3.59, 3.71, 3.80 (each 3H, s, OCH_3), 3.81—3.94 (18H in total, m, 6 × OCH_3), 4.00 (2H, br s, $-CH_2-$), 4.20 (2H, m, 3, 3′-H), 4.79, 4.83 (each 1H, s, 2, 2′-H), 6.13 (1H, s, 6-H), 6.27 (1H, s, 8′-H), 6.71 (4H, s, B, B′-ring-H). ^{13}C-NMR ($CDCl_3$): 17.8 ($-CH_2-$), 28.5 (C-4, 4′), 55.4, 55.8, 56.2, 60.5, 60.8 (OCH_3), 66.6, 66.8 (C-3, 3′), 78.3 (C-2, 2′), 89.3 (C-6), 96.2 (C-8′), 100.2 (C-4a), 103.2, 103.5 (B, B′-ring C-2,6), 104.6 (C-4′a), 110.6 (C-8), 117.1 (C-6′), 134.0, 134.5 (B, B′-ring C-1), 137.4, 137.5 (B, B′-ring C-4), 153.5, 153.6 (B, B′-ring C-3, 5), 152.6, 153.0, 156.7, 157.5, 158.4, 158.8 (C-5, 7, 8a, 5′, 7′, 8′a).

Preparation of 26, 27 and 28 A 4% solution of formaldehyde in EtOH (40 ml) was added stepwise to an ice-cooled solution of **23** (5 g) in 0.02 N HCl–EtOH (50 ml). The reaction mixture was stirred for 1 h, then directly applied to a column of Sephadex LH-20. Elution with EtOH gave a mixture of **26**, **27** and **28**, which was separated by Fuji gel and Bondapak C_{18} chromatographies with H_2O–MeOH to afford **26** (1.2 g) and **27** (634 mg), together with **28** (102 mg) as an off-white amorphous powder, $[\alpha]_D^{19}$ −147.2° (c=0.3, acetone). *Anal.* Calcd for $C_{45}H_{36}O_{22}\cdot 6H_2O$: C, 52.12; H, 4.66. Found: C, 52.31; H, 4.57. FAB-MS m/z: 929 $(M+H)^+$. ^{1}H-NMR (acetone-d_6): 2.75—3.22 (4H, m, 4-H), 3.78 (2H, br s, $-CH_2-$), 5.03 (2H, s, 2-H), 5.54 (2H, m, 3-H), 6.17 (2H, s, 8-H), 6.57 (4H, s, 2′, 6′-H), 6.96 (4H, s, galloyl-H). ^{13}C-NMR (acetone-d_6 + D_2O): 17.5 ($-CH_2-$), 26.9 (C-4), 69.7 (C-3), 77.9 (C-2), 95.9 (C-8), 100.4 (C-4a), 106.6 (C-2′, 6′), 107.6 (C-6), 109.9 (galloyl C-2, 6), 121.2 (galloyl C-1), 130.3 (C-1′), 133.0 (C-4′), 139.0 (galloyl C-4), 145.8, 146.0 (C-3′, 5′, galloyl C-3, 5), 153.2, 154.7 (C-5, 7, 8a), 166.7 (COO).

Preparation of 26a, 27a and 28a A 4% solution of formaldehyde in EtOH (40 ml) was added stepwise to an ice-cooled solution of **23** (5 g) in 0.02 N HCl–EtOH (50 ml). Work-up as described above yielded **26a** (507 mg), **27a** (571 mg) and **28a** (85 mg) as an off-white amorphous powder, $[\alpha]_D^{22}$ −71.3° (c=0.9, acetone). *Anal.* Calcd for $C_{31}H_{28}O_{14}\cdot 5/2H_2O$: C, 55.60; H, 4.97. Found: C, 55.69; H, 4.91. ^{1}H-NMR (acetone-d_6 + D_2O): 2.60—3.04 (4H, m, 4-H), 3.76 (2H, br s, $-CH_2-$), 4.19 (2H, m, 3-H), 4.78 (2H, s, 2-H), 6.13 (2H, s, 8-H), 6.57 (4H, s, 2′, 6′-H). ^{13}C-NMR (acetone-d_6 + D_2O): 17.4 ($-CH_2-$), 29.2 (C-4), 66.8 (C-3), 79.2 (C-2), 95.8 (C-8), 101.4 (C-4a), 106.8 (C-2′, 6′), 107.4 (C-6), 131.1 (C-1′), 132.9 (C-4′), 146.0 (C-3′, 5′), 152.9, 154.8 (C-5, 7, 8a).

Methylation of 28a A mixture of **28a** (46 mg), Me_2SO_4 (0.3 ml) and anhydrous K_2CO_3 (0.5 g) in dry acetone (8 ml) was refluxed for 3 h with stirring. After removal of inorganic salts by filtration, the filtrate was concentrated to a syrup, which was chromatographed over silica gel. Elution with benzene–acetone (1:3, v/v) gave the decamethyl ether (**28b**) (13 mg) as an off-white amorphous powder, $[\alpha]_D^{22}$ −34.9° (c=1.0, $CHCl_3$). *Anal.* Calcd for $C_{41}H_{48}O_{14}$: C, 64.38; H, 6.33. Found: C, 64.23; H, 6.49. ^{1}H-NMR ($CDCl_3$): 2.86—3.16 (4H, m, 4-H), 3.57, 3.75 (each 3H, s, OCH_3), 3.80—3.93 (24H in total, m, 8 × OCH_3), 3.95 (2H, br s, $-CH_2-$), 4.27 (2H, m, 3-H), 4.94 (2H, s, 2-H), 6.37 (2H, s, 8-H), 6.73 (4H, s, 2′, 6′-H). ^{13}C-NMR ($CDCl_3$): 17.7 ($-CH_2-$), 28.4 (C-4), 55.8, 56.2, 60.2, 60.8 (OCH_3), 66.6 (C-3), 78.6 (C-2), 96.0 (C-8), 103.4 (C-2′, 6′), 117.1 (C-6), 134.1 (C-1′), 137.7 (C-4′), 153.5 (C-3′, 5′), 152.8, 157.8, 158.4 (C-5, 7, 8a).

Epicatechin-(4β→8)-epigallocatechin 3-*O*-Gallate (29) A tan amorphous powder, $[\alpha]_D^{20}$ −52.6° (c=0.9, acetone). *Anal.* Calcd for $C_{37}H_{30}O_{17}\cdot 2H_2O$: C, 56.78; H, 4.38. Found: C, 56.85; H, 4.48. ^{1}H-NMR (acetone-d_6 + D_2O): 2.80—3.20 (2H, m, 4′-H), 4.00 (1H, br s, 3-H), 4.84 (1H, br s, 4-H), 5.12 (1H, br s, 2′-H), 5.24 (1H, br s, 2-H), 5.56 (1H, m, 3′-H), 6.02 (3H, m, 6, 8,

6′-H), 6.60—7.04 (5H in total, m, B, B′-ring-H), 7.09 (2H, s, galloyl H). ^{13}C-NMR (acetone-d_6+D_2O): 26.8 (C-4′), 36.4 (C-4), 69.3 (C-3′), 72.8 (C-3), 76.8 (C-4′), 77.8 (C-2), 95.6, 96.2, 97.0 (C-6, 8, 6′), 99.2 (C-4′a), 101.5 (C-4a), 106.3 (B′-ring C-2, 6), 107.6 (C-8′), 110.2 (galloyl C-2, 6), 115.1, 115.6, 119.1 (B-ring C-2, 5, 6), 121.3 (galloyl C-1), 130.3, 132.1, 132.6 (B-ring C-1, B′-ring C-1, 4), 138.9 (galloyl C-4), 145.0, 145.3, 145.6, 145.9 (B-ring C-3, 4, B′-ring C-3, 5, galloyl C-3, 5), 154.2, 155.4, 155.7, 157.3, 157.7 (C-5, 7, 8a, 5′, 7′, 8′a), 166.8 (COO).

Tannase Hydrolysis of 29 A solution of **29** (33 mg) in H_2O (5 ml) was treated wih tannase for 10 min. Work-up as described above gave gallic acid and **29a** (10 mg) as a tan amorphous powder, $[\alpha]_D^{19}$ +24.6° (c=0.7, acetone). *Anal.* Calcd for $C_{30}H_{26}O_{13}\cdot 11/2H_2O$: C, 51.94; H, 5.37. Found: C,51.93; H, 4.91. ^{1}H-NMR (acetone-d_6+D_2O): 2.64—3.07 (2H, m, 4′-H), 4.00 (1H, br s, 3-H), 4.33 (1H, m, 3′-H), 4.72 (1H, br s, 4-H), 4.87 (1H, br s, 2′-H), 5.08 (1H, s, 2-H), 5.98—6.08 (3H in total, m, 6, 8, 6′-H), 6.67—7.00 (5H in total, m, B, B′-ring-H).

Epicatechin 3-*O*-Gallate-(4β→8)-epigallocatechin 3-*O*-Gallate (30) A tan amorphous powder, $[\alpha]_D^{21}$ −55.8° (c=0.8, acetone). *Anal.* Calcd for $C_{44}H_{34}O_{21}\cdot 2H_2O$: C, 56.53; H, 4.10. Found: C, 56.19; H, 4.17. ^{1}H-NMR (acetone-d_6+D_2O): 2.75—3.22 (2H, m, 4′-H), 4.78 (1H, m, 4-H), 4.94 (1H, m, 2′-H), 5.42 (2H, m, 3, 3′-H), 5.67 (1H, br s, 2-H), 5.97 (2H, m, 6, 8′-H), 6.15 (1H, s, 6′-H), 6.54 (2H, s, B′-ring-H), 6.72 (2H, br s, B-ring 5, 6-H), 6.98 (3H, br s, B-ring 2-H, galloyl H), 7.07 (2H, s, galloyl H). ^{13}C-NMR (acetone-d_6+D_2O): 26.2 (C-4′), 33.8 (C-4), 69.7 (C-3′), 75.0 75.7 (C-2, C-3), 78.1 (C-2′), 95.6, 96.2, 97.0 (C-6, 8, 6′), 99.0 (C-4′a), 102.1 (C-4a), 107.0 (C-8′, B′-ring C-2, 6), 110.2 (galloyl C-2, 6), 115.0, 115.7, 119.3 (B-ring C-2, 5, 6), 121.6 (galloyl C-1), 130.4, 131.3, 132.7 (B-ring C-1, B′-ring C-1, 4), 139.0 (galloyl C-4), 145.3, 145.4, 145.8 (B-ring C-3, 4, B′-ring C-3, 5, galloyl C-3, 5), 154.8, 155.8, 156.9, 157.0, 157.3 (C-5, 7, 8a, 5′, 7′, 8′a), 166.6 (COO).

Tannase Hydrolysis of 30 A solution of **30** (19 mg) in H_2O (5 ml) was treated with tannase for 10 min. Work-up as described above gave gallic acid and **19a** (6 mg)

Preparation of 30[20] A mixture of **29b** (250 mg) and **23** (1.25 g) in 0.01 N ethanolic HCl (20 ml) was refluxed for 3 h. The reaction mixture was directly applied to a column of Sephadex LH-20, pre-swollen in EtOH. Elution with EtOH afforded a crude product, which was purified by chromatography on Fuji gel with H_2O–MeOH (1 : 0—1 : 1, v/v) to yield **30** (47 mg).

Catechin-(4α→8)-epigallocatechin 3-*O*-Gallate (31) A tan amorphous powder, $[\alpha]_D^{23}$ −236.6° (c=1.0, acetone). *Anal.* Calcd for $C_{37}H_{30}O_{17}\cdot 6H_2O$: C, 51.99; H, 4.95. Found: C, 52.02; H, 4.48. ^{1}H-NMR (acetone-d_6): 2.80—3.20 (2H, m, 4′-H), 4.20—5.60 (5H in total, m, 2, 3, 4, 2′, 3′-H), 5.91—6.32 (3H in total, m, 6, 8, 6′-H), 6.64—7.16 (7H in total, m, B, B′-ring-H).

Tannase Hydrolysis of 31 A solution of **31** (52 mg) in H_2O (5 ml) was treated with tannase for 10 min. Work-up as described above gave gallic acid and **9** (23 mg).

Prodelphinidin B-4 3′-*O*-Gallate (32) A tan amorphous powder, $[\alpha]_D^{23}$ −262.2° (c=1.2, acetone). *Anal.* Calcd for $C_{37}H_{30}O_{18}\cdot 6H_2O$: C, 51.04; H, 4.86. Found: C, 51.25; H, 4.54. ^{1}H-NMR (acetone-d_6): 2.80—3.20 (2H, m, 4′-H), 4.12—5.54 (5H in total, m, 2, 3, 4, 2′, 3′-H), 5.90—6.30 (3H in total, m, 6, 8, 6′-H), 6.42, 6.63, 6.76, 7.01, 7.08 (6H in total, each s, B, B′-ring-H, galloyl H).

Tannase Hydrolysis of 32 A solution of **32** (30 mg) in H_2O (5 ml) was treated with tannase for 10 min. Work-up as described above gave gallic acid and **11** (26 mg).

Epicatechin 3-*O*-Gallate-(4β→6)-epigallocatechin 3-*O*-Gallate (33) A tan amorphous powder, $[\alpha]_D^{26}$ +12.8° (c=0.7, acetone). *Anal.* Calcd for $C_{44}H_{34}O_{21}\cdot 7/2H_2O$: C, 54.94; H, 4.30. Found: C, 55.13; H, 4.76. ^{1}H-NMR (acetone-d_6+D_2O): 2.94—3.20 (2H, m, 4′-H), 4.62 (1H, s, 4-H), 5.07 (2H, br s, 3, 2′-H), 5.42 (1H, s, 2-H), 5.49 (1H, m, 3′-H), 6.03, 6.13 (each 1H, d, J=2 Hz, 6, 8-H), 6.17 (1H, s, 8′-H), 6.71 (2H, s, B′-ring-H), 6.75—7.13 (3H in total, m, B-ring 2, 5, 6-H), 7.07 (4H, s, 2×galloyl H). ^{13}C-NMR (acetone-d_6+D_2O): 26.7 (C-4′), 34.5 (C-4), 70.0 (C-3′), 75.2 (C-3, 2′), 77.9 (C-2), 95.3, 96.3, 97.1 (C-6, 8, 8′), 99.3, 100.0 (C-4a, 4′a), 106.6 (B′-ring C-2, 6), 107.2 (C-6′), 110.4 (2×galloyl C-2, 6), 114.8, 115.7 (B-ring C-2, 5), 118.9 (B-ring C-6), 120.3, 121.3 (galloyl C-1), 130.4, 130.7, 133.0 (B-ring C-1, B′-ring C-1, 4), 139.0, 139.6 (galloyl C-4), 145.3, 145.8, 146.0 (B-ring C-3, 4, B′-ring C-3, 5, 2×galloyl C-3, 5), 155.3, 155.9, 157.0, 157.8, 158.3 (C-5, 7, 8a, 5′, 7′, 8′a), 166.8, 168.2 (COO).

Thiolytic Degradation of 33 A mixture of **33** (2 mg), benzylmercaptan (0.2 ml) and acetic acid (0.1 ml) in EtOH (1 ml) was heated under reflux for 3 h with stirring. The reaction mixture was directly analyzed by TLC and high performance liquid chromatography (HPLC) to detect (−)-epicatechin 3-*O*-gallate 4β-benzylthioether (**29a**) [TLC: *Rf* 0.34, benzene–ethyl formate–formic acid (5 : 4 : 1); *Rf* 0.55, benzene–ethyl formate–formic acid (3 : 6 : 1). HPLC: t_R 10.3 min, TSK gel ODS-80T (40% CH_3CN–H_2O, 1.0 ml/min)] and (−)-epigallocatechin 3-*O*-gallate (**23**) [TLC: *Rf* 0.07, benzene–ethyl formate–formic acid (5 : 4 : 1); *Rf* 0.24, benzene–ethyl formate–formic acid (3 : 6 : 1). HPLC: t_R 6.0 min, TSK gel ODS-80T (40% CH_3CN–H_2O, 1.0 ml/min)].

Epigallocatechin 3-*O*-Gallate-(4β→6)-epicatechin 3-*O*-Gallate (34) A tan amorphous powder, $[\alpha]_D^{21}$ +14.5° (c=0.7, acetone). *Anal.* Calcd for $C_{44}H_{34}O_{21}\cdot 9H_2O$: C, 49.81; H, 4.94. Found: C, 49.76; H, 4.86. ^{1}H-NMR (acetone-d_6+D_2O): 2.83—3.17 (2H, m, 4′-H), 4.61 (1H, s, 4-H), 5.08 (1H, br s, 3-H), 5.13 (1H, br s, 2′-H), 5.35 (1H, s, 2-H), 5.53 (1H, m, 3′-H), 6.01, 6.12 (each 1H, d, J=2 Hz, 6, 8-H), 6.16 (1H, s, 8′-H), 6.56 (2H, s, B-ring-H), 6.77 (1H, d, J=8 Hz, B′-ring 5-H), 6.93 (1H, dd, J=8, 2 Hz, B′-ring 6-H), 7.05 (4H, s, 2×galloyl H), 7.12 (1H, d, J=2 Hz, B′-ring 2-H). ^{13}C-NMR (acetone-d_6+D_2O): 27.4 (C-4′), 34.5 (C-4), 69.9 (C-3′), 75.2 (C-2, 3), 78.0 (C-2′), 95.4, 96.4, 97.1 (C-6, 8, 8′), 99.3, 100.1 (C-4a, 4′a), 106.6 (B-ring C-2, 6), 107.2 (C-6′), 110.0, 110.2 (galloyl C-2, 6), 114.9, 115.7, 118.9 (B′-ring C-2, 5, 6), 120.5, 121.3 (galloyl C-1), 130.2, 131.0, 133.0 (B-ring C-1, 4, B′-ring C-1), 139.0, 139.6 (galloyl C-4), 145.4, 145.9, 146.1 (B-ring C-3, 5, B′-ring C-3, 4, 2×galloyl C-3, 5), 155.5, 156.0, 157.0, 157.8, 158.5 (C-5, 7, 8a, 5′, 7′, 8′a), 166.7, 168.3 (COO).

Thiolytic Degradation of 34 A mixture of **34** (2 mg), benzylmercaptan (0.2 ml) and acetic acid (0.1 ml) in EtOH (1 ml) was heated under reflux for 3 h with stirring. The reaction mixture was directly analyzed by TLC and HPLC to detect (−)-epigallocatechin 3-*O*-gallate 4β-benzylthioether (**34a**) [TLC: *Rf* 0.23, benzene–ethyl formate–formic acid (5 : 4 : 1); *Rf* 0.44, benzene–ethyl formate–formic acid (3 : 6 : 1). HPLC: t_R 6.5 min, TSK gel ODS-80T (40% CH_3CN–H_2O, 1.0 ml/min)] and (−)-epicatechin 3-*O*-gallate (**34b**) [TLC: *Rf* 0.13, benzene–ethyl formate–formic acid (5 : 4 : 1); *Rf* 0.35, benzene–ethyl formate–formic acid (3 : 6 : 1). HPLC: t_R 14.3 min, TSK gel ODS-80T (40% CH_3CN–H_2O, 1.0 ml/min)].

Epiafzelechin 3-*O*-Gallate-(4β→6)-epigallocatechin 3-*O*-Gallate (35) A tan amorphous powder, $[\alpha]_D^{21}$ +22.2° (c=1.2, acetone). *Anal.* Calcd for $C_{44}H_{34}O_{20}\cdot 4H_2O$: C, 55.35; H, 4.43. Found: C, 54.96; H, 4.74. ^{1}H-NMR (acetone-d_6): 3.04 (2H, m, 4′-H), 4.66 (1H, s, 4-H), 5.08 (1H, br s, 2′-H), 5.12 (1H, br s, 3-H), 5.48 (1H, s, 2-H), 5.58 (1H, m, 3′-H), 6.02, 6.14 (each 1H, d, J=2 Hz, 6, 8-H), 6.15 (1H, s, 8′-H), 6.66 (2H, s, B′-ring-H), 6.76, 7.31 (each 2H, d, J=9 Hz, B-ring 2, 3, 5, 6-H), 7.05, 7.06 (each 2H, s, galloyl H). ^{13}C-NMR (acetone-d_6+D_2O): 27.0 (C-4′), 34.5 (C-4), 70.0 (C-3′), 75.2 (C-2, 3), 78.0 (C-2′), 95.3, 96.4, 97.0 (C-6, 8, 8′), 99.3, 100.0 (C-4a, 4′a), 106.6 (B-ring C-2, 6), 107.2 (C-6′), 110.0 (2×galloyl C-2, 6), 115.7 (B′-ring C-3, 5), 120.4, 121.3 (galloyl C-1), 128.7 (B′-ring C-2, 6), 129.8 (B′-ring C-1), 130.5 (B-ring C-4), 133.0 (B-ring C-1), 139.1, 139.6 (galloyl C-4), 145.7, 146.0, (B-ring C-3, 5, 2×galloyl C-3, 5), 155.3, 155.9, 157.0, 157.6, 157.8, 158.3 (C-5, 7, 8a, 5′, 7′, 8′a), 166.9, 167.0 (COO).

Tannase Hydrolysis of 35 A solution of **35** (11 mg) in H_2O (5 ml) was treated with tannase for 10 min. Work-up as described above gave gallic acid and **35a** (5 mg) as an off-white amorphous powder, $[\alpha]_D^{19}$ +80.6° (c=0.7, acetone). *Anal.* Calcd for $C_{30}H_{26}O_{12}\cdot 5H_2O$: C, 53.89; H, 5.43. Found: C, 53.43; H, 5.11. ^{1}H-NMR (acetone-d_6): 2.50—2.94 (2H, m, 4′-H), 4.06 (1H, br s, 3-H), 4.18 (1H, m, 3′-H), 4.01 (1H, br s, 4-H), 4.76 (1H, br s, 2′-H), 5.01 (1H, s, 2-H), 6.07, 6.13 (each 1H, d, J=2 Hz, 6, 8-H), 6.09 (1H, s, 8′-H), 6.59 (2H, s, B′-ring-H), 6.84, 7.27 (each 2H, d, J=8 Hz, B-ring 2, 3, 5, 6-H).

Thiolytic Degradation of 35 A mixture of **35** (1 mg), benzylmercaptan (0.2 ml) and acetic acid (0.1 ml) in EtOH (1 ml) was heated under reflux for 3 h with stirring. The reaction mixture was directly analyzed by TLC to detect (−)-epiafzelechin 4β-benzylthioether (**35b**) [TLC: *Rf* 0.58, benzene–ethyl formate–formic acid (5 : 4 : 1), *Rf* 0.65, benzene–ethyl formate–formic acid (3 : 6 : 1)] and (−)-epigallocatechin (**23a**) [*Rf* 0.13, benzene–ethyl formate–formic acid (5 : 4 : 1), *Rf* 0.35, benzene–ethyl formate–formic acid (3 : 6 : 1)].

Prodelphinidin A-2 3′-*O*-Gallate (36) A tan amorphous powder, $[\alpha]_D^{20}$ −60.1° (c=0.5, acetone). *Anal.* Calcd for $C_{37}H_{28}O_{18}\cdot 2H_2O$: C, 55.78; H, 4.05. Found: C, 55.80; H, 4.40. FAB-MS m/z: 761 $(M+H)^+$. ^{1}H-NMR (acetone-d_6+D_2O): 2.82—3.30 (2H, m, 4′-H), 4.16 (1H, d, J=4 Hz, 3-H), 4.50 (1H, d, J=4 Hz, 4-H), 5.15 (1H, m, 3′-H), 6.09, 6.29 (each 1H, d, J=2 Hz, 6, 8-H), 6.15 (1H, s, 6′-H), 6.78, 6.88 (each 2H, s, B, B′-ring-H), 7.17 (2H, s, galloyl-H). ^{13}C-NMR (acetone-d_6+D_2O): 27.3 (C-4′), 28.5 (C-4), 67.3 (C-3), 69.9 (C-3′), 79.9 (C-2′), 96.4, 97.8 (C-6, 8, 6′), 99.6 (C-4′a), 101.2 (C-4a), 103.7 (C-2), 106.6 (B, B′-ring C-2, 6, C-8′), 110.4 (galloyl C-2, 6), 121.1 (galloyl C-1), 129.6, 131.4 (B, B′-ring C-4), 133.5, 134.7 (B, B′-ring C-1), 139.2 (galloyl C-4), 145.7, 146.0, 146.2 (B, B′-ring C-3, 5, galloyl C-3, 5), 151.3, 152.2, 153.6 (C-5′, 7′, 8′a), 155.7, 156.5, 157.5 (C-5, 7, 8a),

166.8 (COO).

Tannase Hydrolysis of 36 A solution of **36** (9 mg) in H_2O (3 ml) was treated with tannase for 10 min. Work-up as described above gave gallic acid and **36a** (3 mg) as an off-white amorphous powder, $[\alpha]_D^{19}$ +54.3° (c = 0.3, acetone). ^{1}H-NMR (acetone-d_6): 2.86—2.90 (2H, m, 4′-H), 4.13 (1H, d, J = 3 Hz, 3-H), 4.29 (1H, m, 3′-H), 4.37 (1H, d, J = 3 Hz, 4-H), 4.87 (1H, s, 2′-H), 6.01, 6.09 (each 1H, d, J = 2 Hz, 6, 8-H), 6.15 (1H, s, 6′-H), 6.78, 6.81 (each 2H, s, B, B′-ring-H).

Preparation of 36 A mixture of **3** (200 mg), sodium biocarbonate (50 mg) and hydrogen peroxide (0.5 ml) in EtOH (20 ml) was left standing at room temperature for 24 h. The reaction mixture was neutralized with Amberlite IR-120B (H^+ form), and the solvent was evaporated off *in vacuo*. The residue was applied to a column of Sephadex LH-20 (EtOH) to afford crude **36**, which was purified on a column of Bondapak C_{18} (H_2O–MeOH, 1 : 0—1 : 1, v/v) to give pure **36** (25 mg).

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