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Constituents of Chinese Crude Drug "Kushen" (the Root of *Sophora flavescens* Ait.). Isolation of Five New Flavonoids and Formononetin[1]

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From the Chinese crude drug, "Kushen" (Japanese name "Kujin") (the root of *Sophora flavescens* Ait.) five new flavonoids, kuraridinol (I), kurarinol (II), neokurarinol (III), nor-kurarinol (IV), isokurarinone (V) (each named by us) and formononetin were isolated, whose structures have been established by spectral and chemical data.

In previous papers,[3,4] we reported the isolation and the structure elucidation of four new flavonoids (isoanhydroicaritin,[3] nor-kurarinone,[4] kurarinone,[4] kuraridin[4]) and the characterization of three flavonoids (xanthohumol,[3] isoxanthohumol,[3] nor-anhydroicaritin[3]) as the constituents of the root of *Sophora angustifolia* Sieb. et Zucc.[5,6]

During the course of our studies on the constituents of the Chinese crude drug, "Kushen" (苦参) (Japanese name "Kujin") (the root of *Sophora flavescens* Ait.[6]), five new flavonoids, kuraridinol (I), kurarinol (II), neokurarinol (III), nor-kurarinol (IV) and isokurarinone (V) (each named by us) and formonometin have been isolated from the ether-soluble fraction of the methanol extract.

The present paper deals with the structures of these flavonoids.

Kuraridinol (I) was obtained as yellow needles, mp 123°, M^+ 456, $C_{26}H_{32}O_7$. It gave the absorption bands of hydroxyl, conjugated carbonyl, and benzene ring in its infrared (IR) spectrum. The ultraviolet (UV) spectrum (λ_{max}^{EtOH} nm: 388) suggested the presence of a chalcone ring,[7] and indicated the presence of a hydroxyl group in position 4, according to the significant bathochromic shift[7] of 61 nm after the addition of sodium ethoxide. The nuclear magnetic resonance (NMR) spectrum exhibited the presence of four aromatic protons [δ 6.02 (1H, s, $C_{5'}$–H), δ 6.38 (1H, d, J=2.2 Hz, C_3–H), δ 6.33 (1H, q, J=2.2 Hz, J=9.0 Hz, C_5–H), δ 7.40 (1H, d, J=9.0 Hz, C_6–H)], a methoxyl group [δ 3.82 (3H, s, OCH_3)], four hydroxyl groups [δ 14.90 (1H, s, $C_{2'}$–OH), δ 9.85, 10.09, 10.30 (each 1H, s, R_1=R_2=R_3=H in Chart 1); shifted to δ 14.83, 9.76, 10.00, 10.21 respectively at 55°], and $C_{\alpha,\beta}$–H protons [δ 7.89 (2H, s)]. It also suggested the presence of a lavandulylic side chain: three methyl groups [δ 1.02, 1.13 (each 3H, s, $-\overset{CH_3}{\underset{CH_3}{<}}$), δ 1.64 (3H, s, $-\overset{CH_3}{<}$)], a terminal methylene [δ 4.40—4.60 (2H,

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3) M. Komatsu, T. Tomimori, K. Hatayama, and N. Mikuriya, *Yakugaku Zasshi*, **90**, 463 (1970).

4) K. Hatayama and M. Komatsu, *Chem. Pharm. Bull.* (Tokyo), **19**, 2126 (1971).

5) K. Tsuda, The 86th Annual Meeting of Pharmaceutical Society of Japan, Sendai, Oct., 1966, p. 268.

6) In "Zhong Yao Zhi (中葯志)" (Vol. 1, ed. by the Pharmaceutical Institute, Chinese Academy of Medical Science, Peking, 1959, p. 337), it is described that the root of *Sophora flavescens* Ait. (*S. angustifolia* Sieb. et Zucc.; *S. flavescens* Ait. var. *angustifolia* Kitaga.) belonging to Leguminosae is the origin of "Kushen" (苦参).

7) L. Jurd, "The Chemistry of Flavonoid Compound", ed. by T.A. Geissman, Pergamon Press, London, 1962, pp. 141—147.

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br, $-\langle_{CH_2}$)], a methine and two methylenes [δ 1.10—1.80 (5H, m, Ar–CH_2–$\underline{C}H$–$C\underline{H}_2$–$C\underline{H}_2$–)], but not the presence of benzyl methylne protons being overlapped by solvent. On methylation with dimethyl sulfate, I gave a trimethyl ether (VI), mp 123°, $C_{29}H_{38}O_7$, whose NMR spectrum showed the presence of benzyl methylene protons [δ 2.60—2.70 (2H, m, Ar–$C\underline{H}_2$–)]. Both the NMR spectra of I and VI failed to reveal the presence of a hydroxyl group due to the side chain.

On catalytic hydrogenation, VI gave a tetrahydro derivative (IX), $C_{29}H_{42}O_7$, IR ν_{max}^{KBr} cm^{-1}: 3466 (OH), NMR [δ 0.89, 0.97 (each 3H, each d, each J=3.0 Hz, $^{Ar-}\rangle$-$\langle^{CH_3}_{CH_3}$), δ 2.70—3.50 (4H, m, Ar–CO–$C\underline{H}_2$–$C\underline{H}_2$–), δ 1.18 (6H, s, $-\langle^{CH_3}_{OH}_{CH_3}$)]. Dehydration of IX was accomplished by refluxing IX in methanolic hydrochloric acid to produce X, $C_{29}H_{40}O_6$, M^+ 484, IR (absence of absorption band of hydroxyl), NMR [δ 1.56, 1.65 (each 3H, s, $\diagdown$=$\langle^{CH_3}_{CH_3}$), δ 5.10 (1H, br, $_H\rangle$=$\langle$)]. On catalytic hydrogenation, X yielded a dihydro derivative (XI), mp 99.5°, M^+ 486, $C_{29}H_{42}O_6$. Catalytic hydrogenation of kuraridin trimethyl ether[4] furnished the hexahydro derivative, mp 99.5°, M^+ 486, which was identified with the above-mentioned XI by UV, IR and NMR spectra.

Thus, kuraridinol would be formulated as I.

Kurarinol (II) was obtained as colorless needles, mp 166—169°, M^+ 456, $C_{26}H_{32}O_7$. It also gave the absorption bands of hydroxyl, conjugated carbonyl, and benzene ring in its IR spectrum. The UV spectrum was characteristic of 7-hydroxyflavanone series[4,8] giving the absorption maxima at 287 nm in ethanol and at 335 nm in the presence of sodium hydroxide. The NMR spectrum exhibited the presence of four aromatic protons [δ 6.13 (1H, s, C_6–H), δ 6.36 (1H, q, J=2.2 Hz, J=8.3 Hz, $C_{5'}$–H), δ 6.41 (1H, d, J=2.2 Hz, $C_{3'}$–H), δ 7.29 (1H, d, J=8.3 Hz, $C_{6'}$–H)], a methoxyl group [δ 3.68 (3H, s)], three hydroxyl groups [δ 8.20—9.30 (3H, br); disappeared by the addition of D_2O], C-2 proton [δ 5.40—5.70 (1H, br)], and two C-3 protons [δ 2.50—2.90 (2H, m)] in the flavanone ring. It also indicated the presence of a similar side chain to that of I: three methyl groups, a terminal methylene, a methine and two methylenes, benzyl methylene protons [δ 2.50—2.90 (2H, m)], a hydroxyl group [δ 3.30 (1H, s, $-\langle$OH); disappeared by the addition of D_2O]. On methylation with dimethyl sulfate, II gave two trimethyl ethers, M^+ 498, one of which had a flavanone ring (VII), UV[8] λ_{max}^{EtOH} nm: 286, NMR: δ 3.75 (9H, s, $OCH_3\times3$), δ 3.70 (3H, s, OCH_3), while the other had a chalcone ring, mp 123°, which was identified with VI derived from I by thin-layer chromatography (TLC), and by IR, UV and NMR spectra.

Therefore, kurarinol could be formulated as II.

Neokurarinol (III) was obtained as colorless needles, mp 195.5°, M^+ 470, $C_{27}H_{34}O_7$. The characteristics of IR (hydroxyl, conjugated carbonyl, benzene ring), UV (7-hydroxyflavanone series[8]) and NMR spectra (four aromatic protons, C-2 and C-3 protons) were resembled closely to that of II. The NMR spectrum exhibited the presence of two hydroxyl groups [δ 8.50—9.70 (2H, br)], two methoxyl groups, and it suggested the presence of a similar side chain to that of I and II. Cleavage of III with 5% ethanolic potassium hydroxide afforded a chalcone[7] (VIII), whose UV spectrum was characteristic of 4-hydroxychalcone series[4,7] giving the absorption maxima at 374 nm in ethanol and at 434 nm in the presence of sodium ethoxide. On methylation with dimethyl sulfate, III yielded two dimethyl ethers, M^+ 498, which were identified with VI and VII respectively by TLC, and IR, UV and NMR spectra.

Accordingly, neokurarinol could be formulated as III.

8) Y. Tomita, "Jikken Kagaku Koza, (Experimental chemistry), Suppl. Vol.", Vol. 5, ed. by the Chemical Society of Japan, Maruzen Co., Ltd., Tokyo, 1966, pp. 940—942.

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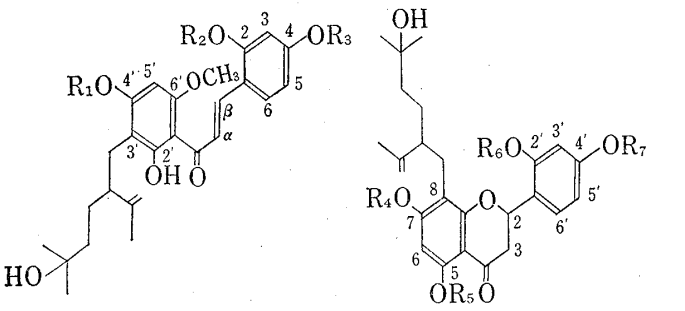
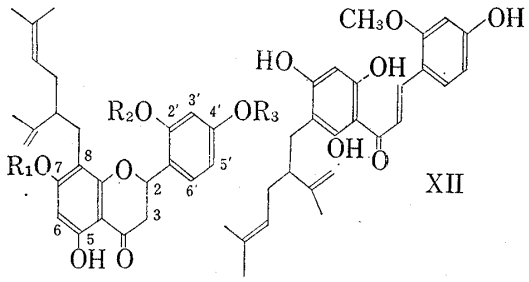


I : $R_1=R_2=R_3=H$ II : $R_4=R_6=R_7=H$, $R_5=CH_3$
VI : $R_1=R_2=R_3=CH_3$ III : $R_4=R_7=H$, $R_5=R_6=CH_3$
VIII : $R_1=R_3=H$, $R_2=CH_3$ IV : $R_4=R_5=R_6=R_7=H$
VII : $R_4=R_5=R_6=R_7=CH_3$



V: $R_1=R_3=H$, $R_2=CH_3$
nor-kurarinone trimethyl ether: $R_1=R_2=R_3=CH_3$

Chart 2

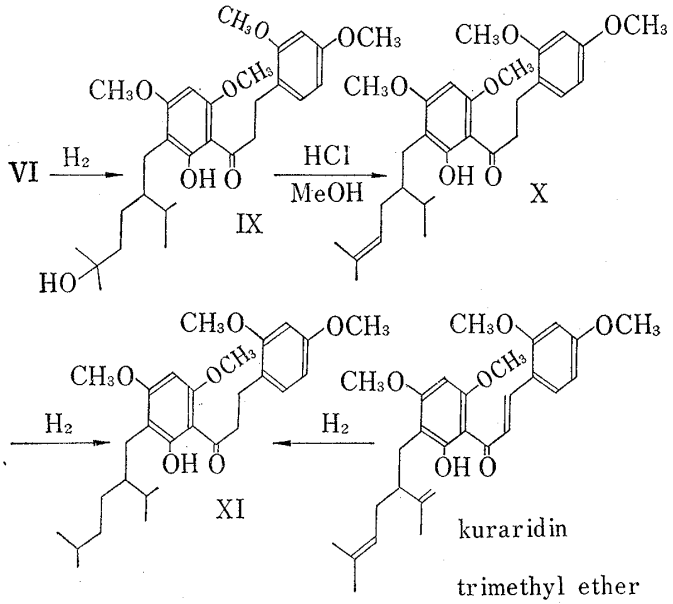


Chart 1

Nor-kurarinol (IV) was obtained as colorless powders, mp 108—116°, M^+ 442, $C_{25}H_{30}O_7$. The characteristics of IR (hydroxyl, conjugated carbonyl), UV (7-hydroxyflavanone series[8]) and NMR spectra (a side chain, four aromatic protons, C-2 and C-3 protons) were resembled closely to that of II and III. The NMR spectrum showed the presence of four hydroxyl groups [δ 12.21 (1H, s, C_5–OH), δ 8.35, 8.64, 9.49 (each 1H, s, OH×3)]. On methylation with dimethyl sulfate, IV gave two tetramethyl ethers, M^+ 498, which were identified with VI and VII respectively by TLC, and IR, UV and NMR spectra. Thus, nor-kurarinol could be formulated as IV.

Isokurarinone (V) was obtained as colorless powders, mp 80—84°, M^+ 438, $C_{26}H_{30}O_6$. The characteristics of IR (hydroxyl, conjugated carbonyl), UV (7-hydroxyflavanone series[4,8]) and NMR spectra (four aromatic protons, C-2 and C-3 protons) were resembled closely to that of II, III and IV. The NMR spectrum exhibited the presence of a methoxyl group, three hydroxyl groups [δ 12.52 (1H, s, C_5–OH), δ 8.50—9.30 (2H, br)] and a lavandulyl[4] side chain: three methyl groups [δ 1.59, 1.63, 1.72 (each 3H, s)], a methine and a methylene [δ 1.29—1.80 (3H, m, Ar–CH_2–C<u>H</u>–C<u>H</u>$_2$–)], a terminal methylene [δ 4.60 (2H, s)], a methine [δ 5.07 (1H, m, $_H$>=<)], and benzyl methylene protons [δ 2.62—2.70 (2H, br, s, Ar–C<u>H</u>$_2$–)]. Cleavage of V with 5% ethanolic potassium hydroxide gave a product (XII), whose UV spectrum was characteristic of 4-hydroxychalcone series,[4,7] giving the absorption maxima at 381 mn in ethanol and at 448 nm in the presence of sodium ethoxide. On methylation with dimethyl sulfate, V gave two methyl ethers, one of which had a chalcone ring, mp 112°, while the other had a flavanone ring, mp 128°, which were identified with kuraridin trimethyl ether[4] and nor-kurarinone trimethyl ether[4] respectively by IR, UV and NMR spectra.

Thus, isokurarinone could be formulated as V.

Formononetin was obtained as colorless needles, mp 262—264°, which was identified with an authentic sample by TLC, and IR, UV and Mass spectra.

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Experimental

All melting points were uncorrected. IR spectra were measured using a JASCO DS-701 spectrophotometer. NMR spectra were taken at 60 MHz with tetramethylsilane as an internal standard using a Hitachi Perkin-Elmer spectrometer, Model R-20. The chemical shifts were given in δ values. The unit (Hz) of coupling constant (J Hz) was abbreviated.

Isolation——The Chinese crude drug, "Kushen" (苦参) (20 kg) was extracted three times with boiling MeOH. The ether soluble part (628 g) of the MeOH extract was column chromatographed on silica gel (4 kg) using hexane, hexane: acetone (2: 1—1: 2) as eluents, and each fraction were cheked by TLC. Isokurarinone (V), formononetin, nor-kurarinol (IV), kuraridinol (I), neokurarinol (III) and kurarinol (II) were eluted in that order. Each compounds were subjected to rechromatography on silica gel to yield V (3 g), formononetin (5 mg), IV (10 g), I (15 g), III (0.5 g) and II (40 g) respectively.

Kuraridinol (I)——I was recrystallized from MeOH to give yellow needles, mp 123°, M^+ 456. *Anal.* Calcd. for $C_{26}H_{32}O_7$: C, 68.40; H, 7.07. Found: C, 68.39; H, 7.07. TLC (Rf): 0.25 (hexane: acetone=1: 1). IR ν_{max}^{KBr} cm^{-1}: 3320 (H), 1610 (conjugated CO), 1549, 1519 (arom. C=C). UV λ_{max}^{EtOH} nm ($\log\varepsilon$): 388 (4.59); $\lambda_{max}^{EtOH\text{-}NaOEt}$ nm: 449. NMR (DMSO-d_6): 1.02, 1.13 (each 3H, s, $-\langle^{CH_3}_{CH_3}$), 1.64 (3H, s, $-\langle^{CH_3}$), 1.10—1.80 (5H, m, Ar-CH_2-C<u>H</u>-C<u>H_2</u>-C<u>H_2</u>-), 4.40—4.60 (2H, m, $-\langle_{CH_2}$), 3.82 (3H, s, OCH_3), 6.02 (1H, s, C_5'-H), 6.33 (1H, q, J=2.2, J=9.0, C_5-H), 6.38 (1H, d, J=2.2, C_3-H), 7.40 (1H, d, J=9.0, C_6-H), 7.89 (2H, s, $C_{\alpha,\beta}$-H), 14.90 (1H, s, C_2'-OH) and 9.85, 10.09, 10.30 (each 1H, s, OH×3, R_1=R_2=R_3=<u>H</u> in Chart 1); each shifted to 14.83, 9.76, 10.00, 10.21 at 55°.

Methylation of I (Formation of VI)——A mixture of I (600 mg), $(CH_3)_2SO_4$ (1 g), K_2CO_3 (3 g) and acetone (30 ml) was refluxed for 2 hr, filtered, and the solvent was evaporated. H_2O (200 ml) was added to the residue which was extracted with ether. The ether layer was washed with H_2O and dried over Na_2SO_4. After evaporation of ether, the residue was chromatographed on silica gel with hexane: acetone (9: 1), giving a product (VI). Compound (VI) was recrystallized from MeOH to give yellow needles, mp 123°, M^+ 498. TLC (Rf): 0.53 (hexane: acetone=2: 1). *Anal.* Calcd. for $C_{29}H_{38}O_7$: C, 69.85; H, 7.68. Found: C, 69.75; H, 7.62. IR ν_{max}^{KBr} cm^{-1}: 3420 (OH), 1613 (conjugated CO). UV λ_{max}^{EtOH} nm: 380; $\lambda_{max}^{EtOH\text{-}AlCl_3}$ nm: 415. NMR ($CDCl_3$): 1.19 (6H, s, $-\langle^{CH_3}_{CH_3}$), 1.35—1.50 (5H, m, Ar-CH_2-C<u>H</u>-C<u>H_2</u>-C<u>H_2</u>-), 1.70 (3H, br, s, $-\langle^{CH_3}$), 2.60—2.70 (2H, m, Ar-C<u>H_2</u>-), 3.83 (6H, s, OCH_3×2), 3.86, 3.90 (each 3H, s, OCH_3×2), 4.50—4.62 (2H, m, $-\langle_{CH_2}$), 5.93 (1H, s, C_5'-H), 6.43 (1H, d, J=2.2, C_3-H), 6.51 (1H, q, J=2.2, J=9.0, C_5-H), 7.50 (1H, d, J=9.0, C_6-H), 7.85, 8.05 (each 1H, d, J=15.0, $C_{\alpha,\beta}$-H), 14.20 (1H, s, C_2'-OH).

Catalytic Hydrogenation of VI (Formation of IX)——VI (400 mg) in EtOH (30 ml) was hydrogenated over PtO_2 (80 mg) as a catalyst. Two moles of H_2 were absorbed during 50 min. After removal of the catalyst, the solvent was evaporated *in vacuo*, and the residue was chromatographed on silica gel with hexane: acetone (9: 1), giving a tetrahydro product (IX). Compound (IX) was recrystallized from MeOH to give colorless needles, mp 100°. *Anal.* Calcd. for $C_{29}H_{42}O_7$: C, 69.29; H, 8.42. Found: C, 69.03; H, 8.33. IR ν_{max}^{KBr} cm^{-1}: 3466 (OH), 1619 (conjugated CO), 1589, 1501 (arom. C=C). NMR ($CDCl_3$): 0.87, 0.97 (each 3H, each d, each J=3.0, $^{Ar-}\rangle\!-\!\langle^{CH_3}_{CH_3}$), 1.18 (6H, s, $-\langle^{CH_3}_{CH_3}$), 1.20—1.70 (6H, m, Ar-CH_2-C<u>H</u>(CH)-C<u>H_2</u>-C<u>H_2</u>-), 2.52 (2H, d, J=6.5, Ar-C<u>H_2</u>-), 2.70—3.50 (4H, m, Ar-CO-C<u>H_2</u>-C<u>H_2</u>-), 3.79, 3.85 (each 6H, s, OCH_3×4), 5.92 (1H, s, C_5'-H), 6.43 (1H, q, J=2.2, J=9.0, C_5-H), 6.45 (1H, d, J=2.2, C_3-H), 7.05 (1H, d, J=9.0, C_6-H), 13.97 (1H, s, OH).

Dehydration of IX (Formation of X)——To a solution of IX (300 mg) in MeOH (50 ml), conc. HCl (14 ml) was dropped and refluxed for 2 hr. After addition of H_2O (300 ml), MeOH was evaporated and the residue was extracted with ether. The ether layer was washed with H_2O and dried over Na_2SO_4. After evaporation of ether, the residue was chromatographed on silica gel with hexane: acetone (9: 1) giving a product (X). Compound (X) was recrystallized from MeOH to give colorless needles, mp 94°, M^+ 484. *Anal.* Calcd. for $C_{29}H_{40}O_6$: C, 71.87; H, 8.32. Found: C, 71.45; H, 8.33. IR ν_{max}^{KBr} cm^{-1}: 1625 (CO), 1593, 1505 (arom. C=C). UV λ_{max}^{EtOH} nm: 290. NMR ($CDCl_3$): 0.80—1.00 (6H, m, $^{Ar-}\rangle\!-\!\langle^{CH_3}_{CH_3}$), 1.40—2.10 (4H, br, Ar-CH_2-C<u>H</u>(CH)-C<u>H_2</u>-), 1.56, 1.65 (each 3H, s, $\rangle\!=\!\langle^{CH_3}_{CH_3}$), 2.50 (2H, d, J=6.8, Ar-C<u>H_2</u>-), 2.70—3.50 (4H, m, Ar-CO-C<u>H_2</u>-C<u>H_2</u>-), 3.79, 3.83 (each 6H, s, OCH_3×4), 5.10 (1H, br, $_H\rangle\!=\!\langle\rangle$), 5.90 (1H, s, C_5'-H), 6.42 (1H, q, J=2.2, J=9.0, C_5-H), 6.43 (1H, d, J=2.2, C_3-H), 7.04 (1H, d, J=9.0, C_6-H), 13.89 (1H, s, OH).

Catalytic Hydrogenation of X (Formation of XI)——X (100 mg) in EtOH (20 ml) was hydrogenated over PtO_2 (20 mg) as a catalyst. One mole of H_2 was absorbed during 40 min. Then, the same procedures described for catalytic hydrogenation of VI were carried out to give a dihydro product (XI). Compound (XI) was recrystallized from MeOH to give colorless needles, mp 99.5°, M^+ 486. *Anal.* Calcd. for $C_{29}H_{42}O_6$: C,

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71.57; H, 8.70. Found: C, 71.68; H, 8.64. IR ν_{max}^{KBr} cm^{-1}: 1627 (conjugated CO), 1593, 1505 (arom. C=C). UV λ_{max}^{EtOH} nm: 290. NMR ($CDCl_3$): 0.75—1.00 (12H, m, $-\langle^{CH_3}_{CH_3}\times 2$), 1.10—1.70 (7H, br, m, Ar-CH_2-CH(CH)-CH_2-CH_2-CH$\langle$), 2.49 (2H, d, J=6.2, Ar-CH_2-), 2.80—3.40 (4H, m, Ar-CO-CH_2-CH_2-), 3.78, 3.83 (each 6H, s, $OCH_3\times 4$), 5.90 (1H, s, C_5'-H), 6.42 (1H, q, J=2.2, J=9.0, C_5-H), 6.43 (1H, d, J=2.2, C_3-H), 7.03 (1H, d, J=9.0, C_6-H), 13.89 (1H, s, OH).

Catalytic Hydrogenation of Kuraridin Trimethyl Ether——Kuraridin trimethyl ether[4] (100 mg) was subjected to catalytic hydrogenation as described for catalytic hydrogenation of X giving colorless needles, mp 99.5°, M^+ 486, which was identified with XI derived from I by UV, IR and NMR spectra.

Kurarinol (II)——II was recrystallized from AcOEt–benzene to give colorles needles, mp 166—169°, M^+ 456. *Anal.* Calcd. for $C_{26}H_{32}O_7$: C, 68.40; H, 7.07. Found: C, 68.35; H, 7.06. TLC (*Rf*): 0.10 (hexane acetone=1: 1). IR ν_{max}^{KBr} cm^{-1}: 3250 (OH), 1645 (conjugated CO), 1595 (arom. C=C). UV λ_{max}^{EtOH} nm (log ε): 287 (4.46); $\lambda_{max}^{EtOH-NaOH}$nm: 335. NMR [$(CD_3)_2CO$]: 1.06, 1.11 (each 3H, $-\langle^{CH_3}_{CH_3}$), 1.30—1.60 (5H, m, Ar-CH_2-CH-CH_2-CH_2-), 1.61 (3H, br, s, $-\langle^{CH_3}$), 2.50—2.90 (4H, m, C_3-H_2 and Ar-CH_2-), 3.30 (1H, s, $-\langle$OH; disappeared by the addition of D_2O), 3.68 (3H, s, OCH_3), 4.51 (2H, br, s, $-\langle_{CH_2}$), 5.40—5.70 (1H, br, C_2-H), 6.13 (1H, s, C_6-H), 6.36 (1H, q, J=2.2, J=8.3, C_5'-H), 6.41 (1H, d, J=2.2, C_3'-H), 7.29 (1H, d, J=8.3, C_6'-H), 8.20—9.30 (3H, br, OH×3; disappeared by the addition of D_2O).

Methylation of II (Formation of VI and VII)——The same procedures described for methylation of I were carried out to give two products.

The first product was recrystallized from MeOH to give colorless needles, mp 123°, M^+ 498, which was was identified with VI derived from I by TLC, and IR and NMR spectra. The second product was obtained as a viscous oil (VII), M^+ 498. TLC (*Rf*): 0.35 (hexane: acetone=2: 1). IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1682 (conjugated CO), 1600 (arom. C=C). UV λ_{max}^{EtOH} nm: 286. NMR (CCl_4): 0.99, 1.08 (each 3H, s, $-\langle^{CH_3}_{CH_3}$), 1.20—1.50 (5H, m, Ar-CH_2-CH-CH_2-CH_2-), 1.58 (3H, br, s, $-\langle^{CH_3}$), 2.40—2.70 (4H, br, m, C_3-H_2 and Ar-CH_2-), 3.70 (3H, s, OCH_3), 3.75 (9H, s, $OCH_3\times 3$), 4.40—4.52 (2H, m, $-\langle_{CH_2}$), 5.35—5.60 (1H, m, C_2-H), 5.98 (1H, s, C_6-H), 6.31 (1H, d, J=2.2, C_3'-H), 6.40 (1H, q, J=2.2, J=8.3, C_5'-H), 7.33 (1H, d, J=8.3, C_6'-H).

Neokurarinol (III)——III was obtained as colorless needles, mp 195.5°, M^+ 470. Gibbs reaction: (−). *Anal.* Calcd. for $C_{27}H_{34}O_7$: C, 68.92; H, 7.28. Found: C, 69.11; H, 6.97. TLC (*Rf*): 0.15 (hexane: acetone= 1: 1). IR ν_{max}^{KBr} cm^{-1}: 3230 (OH), 1650 (conjugated CO), 1592 (arom. C=C). UV λ_{max}^{EtOH} nm (log ε): 287 (4.26); $\lambda_{max}^{EtOH-NaOH}$ nm (log ε): 334 (4.45). NMR [$(CD_3)_2CO$]: 1.15, 1.20 (each 3H, s, $-\langle^{CH_3}_{CH_3}$), 1.40—1.70 (5H, m, Ar-CH_2-CH-CH_2-CH_2-), 1.68 (3H, s, $-\langle^{CH_3}$), 2.40—3.00 (4H, br, Ar-CH_2-, and C_3-H_2), 3.77, 3.81 (each 3H, s, $OCH_3\times 2$), 4.67 (2H, m, $-\langle_{CH_2}$), 5.63 (1H, m, C_2-H), 6.30 (1H, s, C_6-H), 6.55—6.65 (2H, m, C_3'-H, and C_5'-H), 7.47 (1H, d, J=9.0, C_6'-H), 8.50—9.70 (2H, br, OH×2, R_4=R_7=H in Chart 1; disappeared by the addition of D_2O).

Alkali Cleavage of III (Formation of VIII)——A mixture of III (25 mg) and 5% EtOH–KOH (5.5 ml) was agitated for 1 hr at 60°. After addition of H_2O (30 ml), EtOH was evaporated. The reaction mixture was acidified to pH 2 with dil. HCl, extracted with ether, and the ether layer was washed with H_2O, dried over Na_2SO_4. Evaporation of ether left a residue, which was chromatographed on silica gel using hexane: acetone (4: 1), giving an oily product (VIII), UV λ_{max}^{EtOH} nm: 374; $\lambda_{max}^{EtOH-NaOEt}$ nm: 434.

Methylation of III (Formation of VI and VII)——The same procedures described for methylation of I were carried out to give two products, M^+ 498, which were identified with VI and VII respectively by TLC, and IR, UV and NMR spectra.

Nor-kurarinol (IV)——IV was obtained as colorless powders, mp 108—116°, M^+ 442. *Anal.* Calcd. for $C_{25}H_{30}O_7$: C, 67.85; H, 6.83. Found: C, 67.82; H, 6.79. TLC (*Rf*): 0.26 (hexane: acetone=1: 1). IR ν_{max}^{KBr} cm^{-1}: 3415 (OH), 1630 (conjugated CO). UV λ_{max}^{EtOH} nm (log ε): 294 (4.22); $\lambda_{max}^{EtOH-NaOH}$ nm (log ε): 336 (4.43). NMR [$(CD_3)_2CO$]: 1.18 (6H, s, $-\langle^{CH_3}_{CH_3}$), 1.35—1.80 (5H, m, Ar-CH_2-CH-CH_2-CH_2-), 1.58 (3H, s, $-\langle^{CH_3}$), 2.61 (2H, br, s, Ar-CH_2-), 2.70—3.10 (2H, m, C_3-H_2), 4.60 (2H, br, s, $-\langle_{CH_2}$), 5.80 (1H, m, C_2-H), 6.03 (1H, s, C_6-H), 6.50 (1H, q, J=2.2, J=9.0, C_5'-H), 6.52 (1H, d, J=2.2, C_3'-H), 7.42 (1H, d, J=9.0, C_6'-H), 8.35, 8.64, 9.49 (each 1H, s, OH×3, R_4=R_6=R_7=H in Chart 1) and 12.21 (1H, s, C_5-OH); each disappeared by the addition of D_2O.

Methylation of IV (Formation of VI and VII)——The same procedures described for methylation of I were carried out to give two products, M^+ 498, which were identified with VI and VII respectively by TLC, and IR, UV and NMR spectra.

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Isokurarinone (V)——V was obtained as colorless powders, mp 80—84°, M^+ 438. Gibbs reaction: (−). *Anal.* Calcd. for $C_{26}H_{30}O_6$: C, 71.21; H, 6.90. Found: C, 70.89; H, 6.81. TLC (*Rf*): 0.55 (hexane: acetone=1: 1). IR ν_{max}^{KBr} cm^{-1}: 3420 (OH), 1635 (conjugated CO). UV λ_{max}^{EtOH} nm (log ε): 294 (4.26); $\lambda_{max}^{EtOH-NaOH}$ nm (log ε): 335 (4.47). NMR [$(CD_3)_2CO$]: 1.59, 1.63, 1.72 (each 3H, s, $-\langle^{CH_3}$ and $\rangle=\langle^{CH_3}_{CH_3}$), 1.29—1.80 (3H, m, Ar-$CH_2$-C<u>H</u>-C<u>$H_2$</u>-), 2.62—2.70 (2H, br, s, Ar-C<u>H_2</u>-), 2.80—3.20 (2H, m, C_3-H_2), 3.81 (3H, s, OCH_3), 4.60 (2H, s, $-\langle_{CH_2}$), 5.07 (1H, m, $_H\rangle=\langle$), 5.65 (1H, q, J=4.5, J=12.0, C_2-H), 6.02 (1H, s, C_6-H), 6.50 (1H, q, J=2.2, J=9.0, $C_{5'}$-H), 6.55 (1H, d, J=2.2, $C_{3'}$-H), 7.34 (1H, d, J=9.0, $C_{6'}$-H), 8.50—9.30 (2H, br, OH×2) and 12.52 (1H, s, C_5-OH); each disappeared by the addition of D_2O.

Alkali Cleavage of V (Formation of XII)——The same procedures described for alkali cleavage of III were carried out giving an oily product (XII), UV λ_{max}^{EtOH} nm: 381; $\lambda_{max}^{EtOH-NaOEt}$ nm: 448.

Methylation of V (Formation of Kuraridin Trimethyl Ether and Nor-kurarinone Trimethyl Ether)——The same procedures described for methylation of I were carried out giving two products, mp 112° and 128°, which were identified with kuraridin trimethyl ether[4] and nor-kurarinone trimethyl ether[4] respectively by TLC, and IR, UV and NMR spectra.

Formononetin——Recrystallized from hexane–acetone to give colorless needles, mp 262—264°, which was identified with an authentic sample by TLC, and IR, UV and mass spectra.

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