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Hydroxylation of Aliphatic Compounds with *m*-Chloroperbenzoic Acid. Synthesis of Hydroxylated Vitamin K_1 Analogues

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Pristane and 1,5,9,13-tetramethyltetradecyl acetate were treated with *m*-chloroperbenzoic acid in chloroform under reflux to afford hydroxylated derivatives, respectively. The products, 13- and 9-hydroxy-1,5,9,13-tetramethyltetradecyl acetates, were converted to hydroxylated vitamin K_1 analogues *via* the corresponding hydroxyphytols.

We have been studying the biotransformation of terpenoids in rabbits.[1] Compounds administered to mammals are often hydroxylated prior to excretion, a process which is related to detoxification.[2] We are interested in *in vitro* reactions which simulate this biological phenomenon. In 1979 Müller and Schneider reported that alicyclic compounds could be hydroxylated using *m*-chloroperbenzoic acid (*m*-CPBA).[3] Recently we have applied this reaction to dammarane,[4] lupane,[5] and friedelane[5] triterpenoids and have demonstrated the formation of tertiary and secondary alcohols. As a continuation of this work we have investigated the reactions of pristane and phytane derivatives with *m*CPBA and have applied the products of the reaction to the synthesis of vitamin K analogues.

Pristane (**1**) was treated with *m*CPBA in refluxing chloroform for 22 h, after which work-up and chromatography over silica-gel afforded two monohydric tertiary alcohols. ^{1}H NMR spectroscopy indicated that whilst the less polar alcohol, **2** (43% yield[6])[7] [IR 3350 cm^{-1}, δ=72.8 (s)] possessed only one tertiary methyl group [δ=1.15 (3H, s)], the more polar product, **3** (36% yield[6]) [IR 3350 cm^{-1}, δ=71.1 (s)][8] contained a 1-hydroxy-1-methylethyl group [δ=1.21 (6H, s)]. These observations led to structures **2** and **3**, 2,6,10,14-tetramethyl-6-pentadecanol (**2**) and 2,6,10,14-tetramethyl-2-pentadecanol (**3**), respectively. Further support for these structures was furnished by mass spectroscopy. The major peaks in the mass spectrum of **2** occurred at *m/z* 199 and 129 and resulted from bond fission α to the hydroxyl group (Fig. 1). An analogous fragmentation gave rise to the predominant ion with *m/z* 59 in the spectrum of **3**. As the tertiary alcohols are formed in relatively good yield, we examined the reactions of phytane derivatives with *m*CPBA.

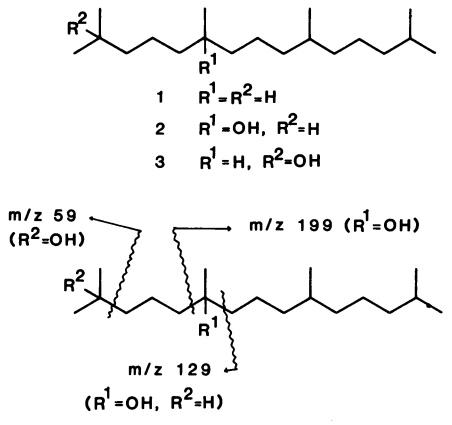
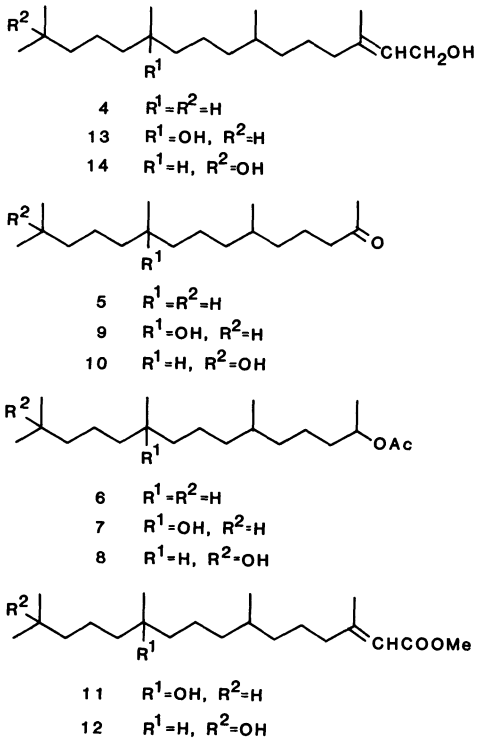
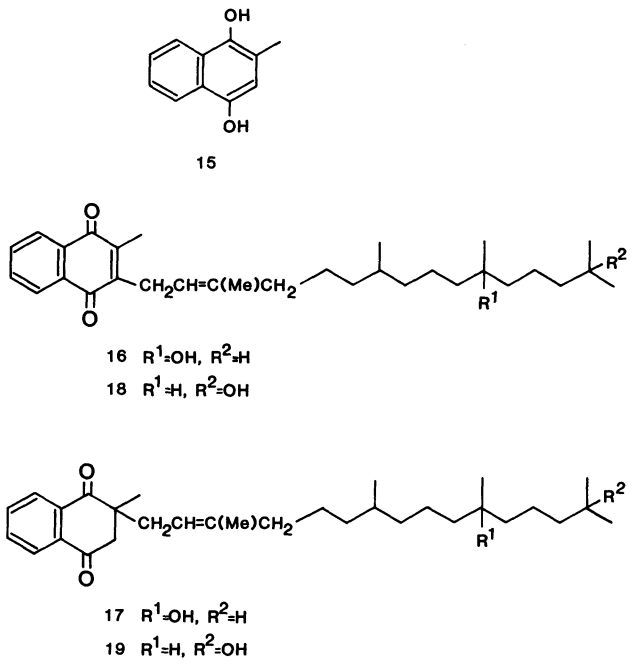


Fig. 1.

Since *m*CPBA reacts with the double bond of phytol (**4**), it was first of all necessary to protect the olefin. However, a simple protecting group was unavailable and we therefore planned to remove the allylic alcohol by ozonolysis; regeneration would be effected by a Wittig reaction at a later stage. The resulting ketone should be more readily protected.

Ozonolysis of phytol (**4**) in methanol at −18 °C followed by zinc/acetic acid reduction gave 6,10,14-trimethyl-2-pentadecanone (**5**)[8,9] in 91% yield after chromatographic purification over silica-gel. When the ethylene acetal of **5** was treated with *m*CPBA in $CHCl_3$ under reflux, many spots on TLC were observed due to the lability of the acetal to the acid formed in the reaction mixture. Therefore, the ketone **5** was reduced by $NaBH_4$ in MeOH followed by acetylation to **6**.[7] The acetate (**6**)[7] was then treated with *m*CPBA in $CHCl_3$ under reflux for 24 h to afford two hydroxylated derivatives after column chromatography over silica-gel. The spectral data of the less polar product (**7**)[7] [IR 3430, 1730, and 1240 cm^{-1}; *m/z* 243; δ=1.15 (3H, s), 1.20 (3H, d, *J*=6.4 Hz), 2.02 (3H, s), and 4.89 (1H, m)] indicated that **7** was 9-hydroxy-1,5,9,13-tetramethyltetradecyl acetate and those of the more polar product (**8**)[7] [IR 3420, 1730, and 1240 cm^{-1}; *m/z* 59; δ=1.21 (6H, s), 2.03 (3H, s), and 4.89 (1H, m)] suggested that **8** was 13-hydroxy-1,5,9,13-tetramethyltetradecyl acetate. The fact that 5-position was not hydroxylated is presumably due to the electrophilic nature of the reagent as described by Deno and Messer.[10] The hydroxy acetates, **7** and **8**, were hydrolyzed by methanolic KOH followed by Jones oxidation to give the corresponding hydroxy ketones, **9**[7] [IR 3450 and 1715 cm^{-1}; *m/z* 199; δ=1.16 (3H, s) and 2.13 (3H, s)] and **10** [IR 3430 and 1715 cm^{-1}; *m/z* 59; δ=1.21 (6H, s) and 2.14 (3H, s)], respectively. The ketone **9** was





allowed to react with the anion prepared from methyl dimethoxyphosphorylacetate with sodium hydride in dry 1,2-dimethoxyethane at rt to yield methyl 11-hydroxy-3,7,11,15-tetramethyl-2-hexadecenoate (**11**)[7] [IR 3410, 1720, and 1645 cm^{-1}; *m/z* 322 $(M-18)^+$; δ=5.66 (bs)] in 49% yield after chromatographic purification. Methyl 15-hydroxy-3,7,11,15-tetramethyl-2-hexadecenoate (**12**) [IR 3400, 1715, and 1645 cm^{-1}; *m/z* 322 $(M-18)^+$ and 59; δ=5.67 (bs)] was prepared in the same manner in 64% yield. Although analysis by GC showed that **11** and **12** were *ca.* 1:1 mixtures of the geometric isomers, further separation was not attempted. Reduction of the methyl esters, **11** and **12**, using $LiAlH_4$ in dry ether gave the desired hydroxylated phytol derivatives, **13**[7] [IR 3310 cm^{-1}; *m/z* 294 $(M-18)^+$; δ=5.40 (m)] and **14** [IR 3330 cm^{-1}; *m/z* 294 $(M-18)^+$ and 59; δ=5.40 (m)], respectively. The structures were fully characterized by IR, NMR, and mass spectra.

The chemistry of vitamin K has been studied extensively[11] and synthesis[11] and biological studies[12] of its derivatives are still undertaken. Several works[12] on the preparation and estimation of hydroxylated vitamin K_1 derivatives have been reported, although the compounds are less active than vitamin K_1 itself. As a demonstration of the synthetic utility of the compounds obtained here, we next carried out the reaction of 2-methyl-1,4-naphthalenediol with the hydroxyphytols.

A mixture of the diol **13** and 2-methyl-1,4-naphthalenediol (**15**) in dioxane was treated with $KHSO_4$ at 40—50 °C for 4 h followed by Ag_2O oxidation. After the usual work-up, the residue was separated by prep TLC (AcOEt–PhH 1:4) to afford the desired 11′-hydroxyvitamin K_1 (**16**)[7] [IR 3580—3250, 1650, and 1610 cm^{-1}; *m/z* 466 (M^+); δ=5.00 (m)] in 17% yield in addition to the by-product, 2-methyl-2-(11-hydroxy-3,7,11,15-tetramethyl-2-hexadecenyl)-2,3-dihydro-1,4-naphthoquinone (**17**)[7] [IR 3580—3310 cm^{-1}; *m/z* 453 $(M-15)^+$; δ=5.03 (m)] in 18% yield. The diol (**14**) was next subjected to a condensation reaction with **15** and oxidation (Ag_2O) in the same manner to yield 15′-hydroxyvitamin K_1 (**18**) [IR 3580—3280 cm^{-1}; *m/z* 466 (M^+), 225 (base peak), and 59; δ=5.00 (m)] in 19% yield and 2-methyl-2-(15-hydroxy-3,7,11,15-tetramethyl-2-hexadecenyl)-2,3-dihydro-1,4-naphthoquinone (**19**) [IR 3580—3300 cm^{-1}; *m/z* 468 (M^+), 174 (base peak), and 59; δ=5.04 (m)] in 20% yield. The structures are consistent with the spectral data. In these reactions dehydration of the newly attached hydroxyl groups was not observed.

In conclusion, we have carried out the hydroxylation of the aliphatic compounds, pristane (**1**) and 1,5,9,13-tetramethyltetradecyl acetate (**6**) using *m*CPBA. In both cases hydroxylation occurred at the tertiary positions. Furthermore we have applied the products to the synthesis of vitamin K analogues. Although the biological activity of these analogues is still undetermined, the methodology may be applicable to other classes of natural products.

Experimental

General Procedures. Infrared (IR) spectra were recorded on a Shimadzu IR-408 infrared spectrometer.

Mass spectra were measured using a Shimadzu LKB-9000B, JEOL D-300, or JEOL HX-100 mass spectrometer operating at 70 eV. GC/MS was operated using PEG-20M (15%) or OV-17 (5%) columns (2 m each) with increasing temperature program (from 80 °C—220 °C, rate: 5 °C/min). ^{1}H and ^{13}C NMR spectra were measured in $CDCl_3$ using a JEOL JNM GX-400 (400 MHz for ^{1}H and 100 MHz for ^{13}C) spectrometer. High performance liquid chromatography (HPLC) analysis was determined on a JASCO liquid chromatograph model TRI ROTAR-V. Analytical and preparative thin layer chromatographies (TLC) were carried out on Kieselgel $60F_{254}$ 0.25 mm and 0.5 mm, respectively. Column chromatography was carried out on Kieselgel 60 (70—230 mesh, Merck).

Reactions of each substrate with *m*-chloroperbenzoic acid (*m*CPBA) were performed by addition of *m*CPBA (1—2 equiv) into a solution of the substrate in chloroform (*ca.* 35 mg/mL) and heating under reflux for 20—30 h. Successive washing of the reaction mixture with aq Na_2SO_3, aq $NaHCO_3$, and brine and evaporation of solvents after drying with $MgSO_4$ gave a residue.

Reaction of Pristane (1) with m-CPBA. Pristane (**1**; 1.0 g) was treated with *m*CPBA (964 mg) in $CHCl_3$ (30 ml) under reflux for 22 h to afford a residue (1.3 g) after work-up. The residue was subjected to column chromatography on silica gel (120 g). Elution with 20% hexane–AcOEt gave 2,6,10,14-tetramethyl-6-pentadecanol (**2**) (289 mg) as an oil: Found: *m/z* 269.2844. Calcd for $C_{18}H_{37}O$: M 269.2844; IR (film) 3350 cm^{-1}; ^{1}H NMR δ=0.86 (3H, d, J=6.6 Hz), 0.87 (6H, d, J=6.6 Hz), 0.88 (6H, d, J=6.8 Hz), and 1.15 (3H, s); MS *m/z* 269 $(M-15)^+$, 199, 129, 111, 69, and 43; ^{13}C NMR δ=19.7 (q), 21.3 (t), 21.7 (t), 22.6 (3×q), 22.7 (q), 24.8 (t), 27.0 (q), 27.9 (d), 28.0 (d), 32.7 (d), 37.3 (t), 37.7 (t), 39.3 (t), 39.6 (t), 42.1 (t), 42.2 (t), and 72.8 (s); and 2,6,10,14-tetramethyl-2-pentadecanol (**3**)[8] (240 mg) as an oil: IR (film) 3350 cm^{-1}; ^{1}H NMR δ=0.85 (3H, d, J=6.3 Hz), 0.86 (3H, d, J=6.4 Hz), 0.87 (6H, d, J=6.6 Hz), and 1.21 (6H, s); MS *m/z* 269 $(M-15)^+$ and 59; ^{13}C NMR δ=19.7 (q), 19.7 (q), 21.8 (t), 22.6 (q), 22.7 (q), 24.5 (t), 24.8 (t), 28.0 (d), 29.2 (2×q), 32.8 (2×d), 37.3 (t), 37.4 (2×t), 37.6 (t), 39.4 (t) 44.3 (t), and 71.1 (s).

Preparation of 6,10,14-Trimethyl-2-pentadecanone (5). Ozone was bubbled through a solution of phytol (**4**; 679 mg) in MeOH (20 mL) at −18 °C for 20 min. Acetic acid (5 mL) was added and the solution was treated with Zn (*ca.* 10 mg) to afford 6,10,14-trimethyl-2-pentadecanone (**5**; 563 mg).[8,9]

Acetalization of 6,10,14-Trimethyl-2-pentadecanone (5). A mixture of the ketone (**5**; 184 mg), ethylene glycol (110 mg), *p*-toluenesulfonic acid (25 mg), and benzene (30 mL) was heated using a Dean-Stark water separator for 5 h yielding the ethylene acetal (55 mg) after work up and prep TLC: ^{1}H NMR δ=0.83—0.87 (m), 1.32 (s), 1.57 (s), and 3.94, (m); MS *m/z* 297 $(M-15)^+$, 87, and 43.

Preparation of 1,5,9,13-Tetramethyltetradecyl Acetate (6). A solution of the ketone (**5**; 2.1 g) in MeOH (10 mL) was treated with $NaBH_4$ (390 mg) at rt for 12 h to afford 6,10,14-trimethyl-2-pentadecanol, which was directly treated with Ac_2O in Py yielding 1,5,9,13-tetramethyltetradecyl acetate (**6**; 2 g) as an oil after usual work-up: Found: *m/z* 252.2787 $(M-CH_3COOH)^+$. Calcd for $C_{18}H_{36}$: M 252.2815; IR (film) 1730 and 1240 cm^{-1}; ^{1}H NMR δ=0.84 (6H, d, J=6.6 Hz), 0.87 (6H, d, J=6.6 Hz), 1.20 (3H, d, J=6.3 Hz), 2.03 (3H, s), and 4.89 (1H, m); MS *m/z* 252 $(M-CH_3COOH)^+$, 126, and 97.

Reaction of 1,5,9,13-Tetramethyltetradecyl Acetate (6) with m-CPBA. A mixture of the acetate (**6**; 3.2 g), *m*CPBA (2.8 g), and $CHCl_3$ (90 mL) was heated under reflux for 24 h. Work-up and column chromatography (elution with hexane–AcOEt) gave 9-hydroxy-1,5,9,13-tetramethyltetradecyl acetate (**7**; 280 mg): oil; Found: *m/z* 310.2873 $(M-H_2O)^+$. Calcd for $C_{20}H_{38}O_2$: M 310.2872; IR (film) 3430, 1730, and 1240 cm^{-1}; ^{1}H NMR δ=0.86 (3H, d, J=6.6 Hz), 0.88 (6H, d, J=6.8 Hz), 1.15 (3H, s), and 1.20 (3H, d, J=6.4 Hz); MS *m/z* 268 $(M-CH_3COOH)^+$, 253, 243, 129, 69, and 43: and 13-hydroxy-1,5,9,13-tetramethyltetradecyl acetate (**8**) (350 mg): oil; Found: *m/z* 313.2790 $(M-CH_3)^+$. Calcd for $C_{19}H_{37}O_3$: M 313.2743; IR (film) 3420, 1730, and 1240 cm^{-1}; ^{1}H NMR δ=0.85 (3H, d, J=6.4 Hz), 0.86 (3H, d, J=6.6 Hz), 1.21 (6H, s), 2.03 (3H, s), and 4.89 (1H, m); MS *m/z* 253, 210, 59, and 43.

Preparation of 10-Hydroxy-6,10,14-trimethyl-2-pentadecanone (9). 9-Hydroxy-1,5,9,13-tetramethyltetradecyl acetate (**7**; 170 mg) was treated with 5% KOH–MeOH at rt for 12 h to yield 10-hydroxy-6,10,14-trimethyl-2-pentadecanol (148 mg), which was oxidized with Jones reagent (4 drops) to 10-hydroxy-6,10,14-trimethyl-2-pentadecanone (**9**; 105 mg) after purification by column chromatography on silica gel (15 g): oil; Found: *m/z* 302.3016 $(M+NH_4)^+$. Calcd for $C_{18}H_{40}O_2N$: M 302.3059; IR (film) 3450 and 1715 cm^{-1}; ^{1}H NMR δ=0.87 (3H, d, J=6.6 Hz), 0.88 (6H, d, J=6.6 Hz), 1.16 (3H, s), 2.13 (3H, s), and 2.41 (2H, t, J=7.6 Hz); MS *m/z* 269 $(M-CH_3)^+$, 199, 181, 69, and 43. ^{13}C NMR δ=19.3 (q), 21.1 (t), 21.2 (t), 21.5 (t), 22.5 (2×q), 26.8 (q), 27.7 (d), 29.6 (q), 32.4 (d), 36.2 (t), 37.3 (t), 39.4 (t), 41.9 (2×t), 43.9 (t), 72.5 (s), and 209.1 (s).

Preparation of 14-Hydroxy-6,10,14-trimethyl-2-pentadecanone (10). 13-Hydroxy-1,5,9,13-tetramethyltetradecyl acetate (**8**; 215 mg) was hydrolyzed and oxidized successively as before to afford 14-hydroxy-6,10,14-trimethyl-2-pentadecanone (**10**; 100 mg) as an oil: Found: *m/z* 302.3010 $(M+NH_4)^+$. Calcd for $C_{18}H_{40}O_2N$: M 302.3059; IR (film) 3430 and 1715 cm^{-1}; ^{1}H NMR δ=0.86 (6H, d, J=6.6 Hz), 1.21 (6H, s), 2.14 (3H, s), and 2.41 (2H, t, J=7.6 Hz); MS *m/z* 269 $(M-CH_3)^+$, 59, and 43; ^{13}C NMR δ=19.5 (q), 19.7 (q), 21.4 (t), 21.7 (t), 24.3 (t), 29.2 (2×q), 29.8 (q), 32.6 (d), 32.7 (d), 36.4 (t), 37.1 (t), 37.3 (t), 37.5 (t), 44.1 (t), 44.2 (t), 71.0 (s), and 209.4 (s).

Preparation of Methyl 11-Hydroxy-3,7,11,15-tetramethyl-2-hexadecenoate (11). To a stirred mixture of sodium hydride (58 mg) and methyl dimethoxyphosphorylacetate (143 mg) in dry DME (3 mL) was added a solution of 10-hydroxy-6,10,14-trimethyl-2-pentadecanone (**9**; 105 mg) in dry DME (2 mL) at rt under an Ar atmosphere. The reaction mixture was stirred overnight. Work-up as usual and column chromatography afforded recovered **9** (30 mg) and methyl 11-hydroxy-3,7,11,15-tetramethyl-2-hexadecenoate (**11**; 62 mg): oil; Found: *m/z* 327.2866 $(M-H_2O)^+$. Calcd for $C_{21}H_{38}O_2$; M 322.2871; IR (film) 3410, 1720, and 1645 cm^{-1}; ^{1}H NMR δ=0.86—0.89 (9H, m), 1.15 (3H, s), 1.88 (d, J=1.2 Hz), 2.15 (d, J=1.2 Hz), 3.67 (s), 3.68 (s), and 5.66 (bs); MS *m/z* 322 $(M-H_2O)^+$, 223, 114, and 69.

Preparation of Methyl 15-Hydroxy-3,7,11,15-tetramethyl-2-hexadecenoate (12). 14-Hydroxy-6,10,14-trimethyl-2-

pentadecanone (**10**; 101 mg) was reacted with the phosphonate reagent as before to afford the starting **10** (34 mg) and methyl 15-hydroxy-3,7,11,15-tetramethyl-2-hexadecenoate (**12**; 77 mg): oil; Found: *m/z* 322.2864 $(M-H_2O)^+$. Calcd for $C_{21}H_{38}O_2$: M 322.2870; IR (film) 3400, 1715, and 1645 cm^{-1}; ^1H NMR δ=0.85—0.89 (6H, m), 1.21 (6H, s), 1.88 (d, *J*=1.2 Hz), 2.15 (d, *J*=1.2 Hz), 3.67 (s), 3.68 (s), and 5.67 (bs); MS *m/z* 332, 293, 114, and 59.

Preparation of 3,7,11,15-Tetramethyl-2-hexadecene-1,11-diol (13). To a stirred solution of methyl 11-hydroxy-3,7,11,15-tetramethyl-2-hexadecenoate (**11**; 26 mg) in dry Et_2O (2 mL) was added $LiAlH_4$ (*ca.* 10 mg) at rt. After 2 h, the reaction mixture was worked up as usual to afford 3,7,11,15-tetramethyl-2-hexadecene-1,11-diol (**13**; 23 mg): oil; Found: *m/z* 330.3362 $(M+NH_4)^+$. Calcd for $C_{20}H_{44}O_2N$: M 330.3372; IR (film) 3310 cm^{-1}; ^1H NMR δ=0.84—0.89 (9H, m), 1.15 (3H, s), 1.66 (s), 1.73 (s), 1.97—2.06 (m), 4.11—4.15 (m), and 5.40 (m); MS *m/z* 294 $(M-H_2O)^+$, 276, 209, 191, 69, 55, and 43.

Preparation of 3,7,11,15-Tetramethyl-2-hexadecene-1,15-diol (14). Methyl 15-hydroxy-3,7,11,15-tetramethyl-2-hexadecenoate (**12**; 17 mg) was reduced with $LiAlH_4$ (*ca.* 10 mg) in dry Et_2O (2 mL) as before to give 3,7,11,15-tetramethyl-2-hexadecene-1,15-diol (**14**; 16 mg): oil; Found: *m/z* 330.3373 $(M+NH_4)^+$ (CI-MS). Calcd for $C_{20}H_{44}O_2N$: M 330.3372; IR (film) 3330 cm^{-1}; ^1H NMR δ=0.84—0.89 (m), 1.21 (s), 1.66 (s), 1.73 (s), 1.99 (m), 4.13 (m), and 5.40 (m); MS *m/z* 294 $(M-H_2O)^+$, 276, 191, 69, and 59.

Preparation of 11'-Hydroxyvitamin K_1 (16). A mixture of 3,7,11,15-tetramethyl-2-hexadecene-1,11-diol (**13**; 11 mg), 2-methyl-1,4-naphthalenediol (64 mg), $KHSO_4$ (42 mg), and dioxane (0.3 mL) was heated at 40—50 °C under Ar for 4 h and worked up as usual. After stirring with Ag_2O in dry Et_2O at rt, prep TLC afforded 11'-hydroxyvitamin K_1 (**16**; 3 mg): oil; Found: *m/z* 466.3400. Calcd for $C_{31}H_{46}O_3$: M 466.3445; IR ($CHCl_3$) 3580—3250, 1650, 1610, 1590, and 1455 cm^{-1}; ^1H NMR δ=0.82—0.90 (m), 1.14 (s), 1.16 (s), 2.19 (s), 3.37 (d, *J*=6.9 Hz), 5.00 (m), 7.68—7.70 (m), and 8.07—8.09 (m); MS *m/z* 466 (M^+), 448, 225, 69, 55, and 43: ^{13}C NMR δ=185.5 (s), 184.6 (s), and 72.9 (s): and 2-methyl-2-(11-hydroxy-3,7,11,15-tetramethyl-2-hexadecenyl)-2,3-dihydro-1,4-naphthoquinone (**17**; 3 mg): oil; Found: *m/z* 453.3356 $(M-CH_3)^+$. Calcd for $C_{30}H_{45}O_3$: M 453.3366; IR ($CHCl_3$) 3580—3310, 1690, 1590, and 1455 cm^{-1}, ^1H NMR δ=0.82—0.88 (m), 1.15 (s), 1.16 (s), 1.29 (s), 1.48 (s), 1.87—1.89 (m), 2.28—2.45 (m), 2.82—3.05 (m), 5.03 (m), 7.71—7.76 (m), and 8.00—8.09 (m); MS *m/z* 453 $(M-CH_3)^+$, 451, 383, 174, 69, 55, and 43.

Preparation of 15'-Hydroxyvitamin K_1 (18). 3,7,11,15-Tetramethyl-2-haxadecene-1,15-diol (**14**; 11 mg) was allowed to react with 2-methyl-1,4-naphthalenediol (63 mg) in dioxane (0.5 mL) using $KHSO_4$ (26 mg) as before to give 15'-hydroxyvitamin K_1 (**18**; 3 mg): oil; Found: *m/z* 466.3452. Calcd for $C_{31}H_{46}O_3$: M 466.3447; IR ($CHCl_3$) 3580—3280, 1650, 1610, 1590, and 1455 cm^{-1}; ^1H NMR δ=0.81—0.88 (m), 1.21 (s), 1.68 (s), 1.77 (s), 2.19 (s), 3.37 (d, *J*=6.8 Hz), 5.00 (m), and 7.68—7.70 (m); MS *m/z* 466 (M^+), 448, 433, 408, 225, 59, and 43; ^{13}C NMR δ=185.5 (s), 184.6 (s), and 71.1 (s): and 2-methyl-2-(15-hydroxy-3,7,11,15-tetramethyl-2-hexadecenyl)-2,3-dihydro-1,4-naphthoquinone (**19**; 4 mg): oil; Found: *m/z* 453.3379 $(M-CH_3)^+$. Calcd for $C_{30}H_{45}O_3$: M 453.3369; IR ($CHCl_3$) 3580—3300, 1690, 1590, 1455, and 1370 cm^{-1}; ^1H NMR δ=0.81—0.87 (m), 1.21 (s), 1.29 (s), 1.48 (s), 1.88 (m), 2.29—2.45 (m), 2.82—3.04 (m), 5.04 (m), 7.72—7.74 (m), and 8.02—8.08 (m); MS *m/z* 468 (M^+), 453, 451, 174, 69, 59, and 43.

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6) Yields shown are isolation yields based on consumed starting materials.

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