Revision of Structures of Nellionol and Dehydronellionol

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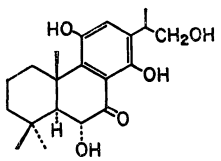
The structures of nellionol and dehydronellionol were revised respectively to 6α,11,12,16-tetrahydroxyabieta-8,11,13-trien-7-one (**12**) and 6,11,12,16-tetrahydroxyabieta-5,8,11,13-tetraen-7-one (**13**) by the following syntheses. A mixture of (15*R*)- and (15*S*)-12-methoxyabieta-8,11,13-trien-16-ol, prepared from 13-acetyl-12-methoxypodocarpa-8,11,13-triene, was converted into 11,12,16-triacetoxyabieta-8,11,13-trien-7-one (**22**) *via* 16-acetoxy-12-benzoyloxyabieta-8,11,13-trien-11-ol. Treatment of **22** with isopropenyl acetate, followed by oxidation with *m*-chloroperbenzoic acid and subsequent acetylation, afforded 6α,11,12,16-tetraacetoxyabieta-8,11,13-trien-7-one, which was hydrolyzed with dilute hydrochloric acid to **12**. The ketone **22** was also converted into **13** *via* 11,12,16-triacetoxyabieta-8,11,13-trien-6-one. The spectral data of **12** and **13** were in good agreement with those of natural nellionol and dehydronellionol.

The novel tricyclic aromatic diterpenes, nellionol and dehydronellionol, have recently been isolated from the root bark of *Premna latifolia* Roxb. by Rao *et al.*[1] On the basis of chemical and spectroscopic studies, they deduced the structures of nellionol and dehydronellionol to be 6α,11,14,16-tetrahydroxyabieta-8,11,13-trien-7-one (**1**) and 6,11,14,16-tetrahydroxyabieta-5,8,11,13-tetraen-7-one (**2**), respectively. Among many naturally-occurring tricyclic diterpenes possessing abietane skeleton, several compounds have two oxygen functions in the C-ring. In these compounds, the oxygen functions are usually present at the C-11 and C-12 positions; this is true for cryptojaponol (**3**),[2] galdosol (**4**),[3] carnosolone (**5**),[4] and carnosic acid (**6**).[5,6] However, Rao *et al.* proposed very unique structures (**1** and **2**) possessing two oxygen functions at the C-11 and C-14 positions and no oxygen function at the C-12 position. It is of interest to confirm the validity of their proposed structures. We therefore examined the published spectral data of these natural products. The ^{1}H NMR spectra of nellionol tetraacetate and dehydronellionol tetraacetate showed, respectively, an aromatic proton signal at δ 8.04 and 8.12. These chemical shifts assigned to the C-12 protons in the proposed structures are in an unusually low field; similar compounds, methyl 11,14-diacetoxy-7-oxoabieta-8,11,13-trien-18-oate (**7**) and 11,14-diacetoxy-13-(acetoxymethyl)podocarpa-8,11,13-trien-7-one (**8**),[7] showed the C-12 proton signals at δ 7.04 and 7.09, respectively. On the other hand, the ^{1}H NMR spectra of carnosolone diacetate (**9**),[4] methyl 11,12-diacetoxy-7-oxoabieta-8,11,13-trien-20-oate (**10**),[3] and methyl 11,12-diacetoxy-7-oxoabieta-5,8,11,13-tetraen-20-oate (**11**)[5] showed singlet signals due to the C-14 aromatic proton at δ 8.23, 8.04, and 8.15, respectively. These spectral data strongly suggested that the aromatic protons in the new natural products are placed at the C-14 position ortho to a carbonyl group. From these ^{1}H NMR spectral analyses together with consideration of the other spectral data, we deduced 6α,11,12,16-tetrahydroxyabieta-8,11,13-trien-7-one (**12**) and 6,11,12,16-tetrahydroxyabieta-5,8,11,13-tetraen-7-one (**13**) to be more preferable structures of nellionol



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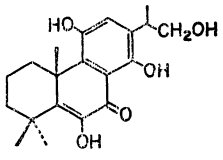

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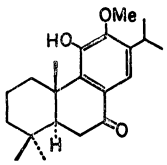

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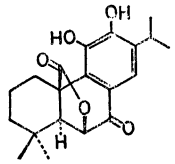

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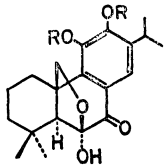
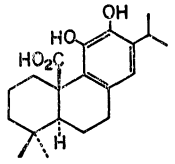


5 R=H
9 R=Ac



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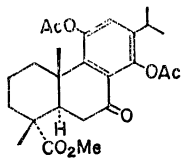

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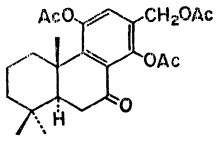

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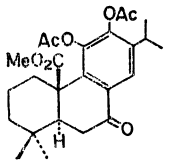

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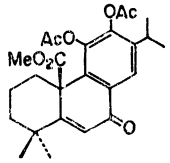

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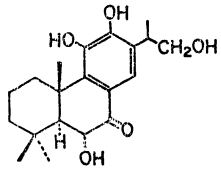

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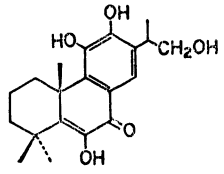


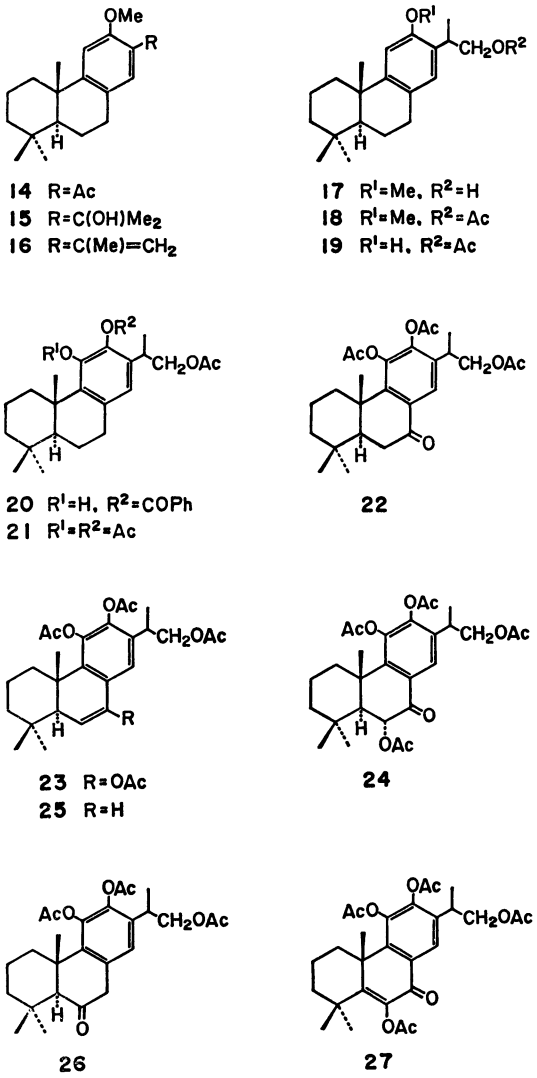
13

and dehydronellionol, respectively. To confirm the validity of our proposal, independent syntheses of **12** and **13**, starting from 13-acetyl-12-methoxypodocarpa-8,11,13-triene (**14**),[8,9] have been attempted.

Grignard reaction of **14** with methylmagnesium iodide in refluxing ether, followed by dehydration of the resulting alcohol (**15**: 86%) in refluxing acetic acid, afforded 12-methoxyabieta-8,11,13,15-tetraene (**16**: 95%), whose ^{1}H NMR spectrum showed singlet signals at δ 2.06 (3H) and 4.96 (2H) due to an isopropenyl group. The tetraene **16** was converted into an epimeric mixture at C-15 of 12-methoxyabieta-8,11,13-trien-16-ol (**17**: 70%) by hydroboration and subsequent oxidation with alkaline hydrogen peroxide. Separation of these epimeric alcohols was unsuccessful. Therefore, the mixture was used in the following reactions. Acetylation of **17** with acetic anhydride in pyridine yielded the corresponding acetate (**18**: 94%), which was treated at room temperature with anhydrous aluminium chloride and ethanethiol in dichloromethane to give 16-acetoxyabieta-8,11,13-trien-12-ol (**19**: 91%). To introduce an oxygen function at the C-11 position, the phenol **19** was oxidized at room temperature with benzoyl peroxide[10] in chloroform to afford 16-acetoxy-12-benzoyloxyabieta-8,11,13-trien-11-ol (**20**: 40%). This was then converted into 11,12,16-triacetoxyabieta-8,11,13-triene (**21**: 90%) by treatment with lithium aluminium hydride in refluxing ether, followed by acetylation with acetic anhydride in pyridine. The ^{1}H NMR spectrum of **21** showed signals due to three acetoxyl groups at δ 1.95 (3H) and 2.22 (6H), and an aromatic proton signal at δ 6.77. Oxidation of **21** with chromium trioxide in acetic acid afforded the corresponding 7-oxo compound (**22**: 73%), whose ^{1}H NMR spectrum showed a singlet signal at δ 8.03 due to an aromatic proton. The downfield shift of the aromatic proton signal from δ 6.77 in **21** to δ 8.03 in **22** must be caused by a deshielding effect of the carbonyl group at the C-7 position. This supported the location of the aromatic proton at C-14. The 7-oxo compound **22** was refluxed with isopropenyl acetate in the presence of *p*-toluenesulfonic acid monohydrate to give 7,11,12,16-tetraacetoxyabieta-6,8,11,13-tetraene (**23**). The ^{1}H NMR spectrum of **23** showed a doublet signal due to an olefinic proton at δ 5.61 and a singlet signal due to an aromatic proton at δ 6.95. Oxidation of **23** with *m*-chloroperbenzoic acid in dichloromethane, followed by acetylation[11] with acetic anhydride in pyridine, afforded 6α,11,12,16-tetraacetoxyabieta-8,11,13-trien-7-one (**24**: 86% from **22**). The α-configuration of the acetoxyl group at the C-6 position in **24** was supported by its ^{1}H NMR spectrum, which showed a doublet signal due to the C-6 proton at δ 5.83 with a coupling constant of 14 Hz, suggesting the β orientation. Hydrolysis of **24** with dilute hydrochloric acid in refluxing ethanol yielded the desired **12** (55%). The ^{1}H NMR spectra of the synthetic **12** and **24** were in good agreement with those of natural nellionol and its tetraacetate.

Subsequently the 7-oxo compound **22** was reduced at room temperature with sodium borohydride in methanol to give a mixture of epimeric alcohols at C-7, which was immediately converted into 11,12,16-triacetoxyabieta-6,8,11,13-tetraene (**25**) by treatment with dilute hydrochloric acid in refluxing methanol and subsequent acetylation[12] with acetic anhydride in pyridine. The ^{1}H NMR spectrum of **25** showed two double doublet signals due to two olefinic protons at δ 5.93 (J=9 and 3 Hz, C_6–H) and 6.45 (J=9 and 3 Hz, C_7–H). The tetraene **25** was further converted into 11,12,16-triacetoxyabieta-8,11,13-trien-6-one (**26**: 40% from **22**) by a series of reactions: oxidation with *m*-chloroperbenzoic acid in dichloromethane at room temperature, treatment with dilute hydrochloric acid in refluxing methanol, and acetylation[12] with acetic anhydride in pyridine. Oxidation of **26** with Jones reagent, followed by treatment with sodium acetate in refluxing acetic anhydride, afforded 6,11,12,16-tetraacetoxyabieta-5,8,11,13-tetraen-7-one (**27**: 52%). Hydrolysis of **27** with dilute hydrochloric acid in refluxing methanol produced the desired **13** (38%). The ^{1}H NMR spectra of the synthetic **13** and **27** were also in good agreement with those of natural dehydronellionol and its tetraacetate.

From the present studies, it is clear that the proposed structures (**1** and **2**) of nellionol and dehydronellionol must be revised to **12** and **13**. However, the stereochemistry of the C-15 position in these natural com-



pounds remained unsettled.

Experimental

The IR spectra were measured in chloroform and the ^{1}H MNR spectra in carbon tetrachloride at 60 MHz, with tetramethylsilane as an internal standard, unless otherwise stated. The chemical shifts are presented in terms of δ values; s: singlet, bs: broad singlet, d: doublet, bd: broad doublet, dd: double doublet, m: multiplet. The column chromatography was performed using Merck silica gel (0.063 mm).

*Methyl 11,14-Diacetoxy-7-oxoabieta-8,11,13-trien-18-oate (**7**).* A mixture of methyl 11,14-dihydroxy-7-oxoabieta-8,11,13-trien-18-oate[13] (19 mg), acetic anhydride (0.4 ml), and pyridine (0.4 ml) was refluxed for 1 h. After the usual work-up, the crude product was chromatographed on silica gel (5.0 g), using ether-benzene (3:97) as the eluent, to give methyl 11-acetoxy-14-hydroxy-7-oxoabieta-8,11,13-trien-18-oate (2 mg: 9%), whose IR spectrum was identical with that of the authentic sample.[13] Further elution with ether-benzene (5:95) gave **7** (15 mg: 64%) as an oil; IR: 1760, 1723, 1684 cm^{-1}; ^{1}H NMR ($CDCl_3$), 90 MHz): 1.05 (3H, d, J=7 Hz) and 1.09 (3H, d, J=7 Hz) (-CH($C\underline{H}_3$)$_2$), 1.29 (3H, s) and 1.33 (3H, s) (C_4-CH_3 and C_{10}-CH_3), 2.32 (3H, s) and 2.34 (3H, s) (2-OCOCH_3), 3.65 (3H, s, -CO_2CH_3), 7.04 (1H, s, C_{12}-H). Found: C, 67.84; H, 7.51%. Calcd for $C_{25}H_{32}O_7$: C, 67.55; H, 7.26%.

*12-Methoxyabieta-8,11,13-trien-15-ol (**15**).* 13-Acetyl-12-methoxypodocarpa-8,11,13-triene (**14**)[8,9] was prepared from (+)-dehydroabietic acid. A solution of **14** (13.1 g) in dry ether (40 ml) was added dropwise to an ethereal solution of methylmagnesium iodide prepared from magnesium turnings (1.3 g) and methyl iodide (3.3 ml) in dry ether (40 ml). The mixture was refluxed for 1.5 h, cooled, poured into ice-dilute hydrochloric acid, and then extracted with ether. The ether extract was washed successively with aqueous sodium thiosulfate and brine, dried over sodium sulfate, and evaporated *in vacuo*. The residue was chromatographed on silica gel (150 g), using benzene and then ether-benzene (9:91) as the eluent, to give **15** (11.8 g: 86%); IR: 3530 cm^{-1}; ^{1}H NMR: 0.96 (6H, s, -$\overset{|}{C}$(CH_3)$_2$), 1.18 (3H, s, C_{10}-CH_3), 1.52 (6H, s, -C($C\underline{H}_3$)$_2$OH), 3.57 (1H, s, -OH), 3.83 (3H, s, -OCH_3), 6.67 (1H, s) and 6.88 (1H, s) (C_{11}-H and C_{14}-H).

*12-Methoxyabieta-8,11,13,15-tetraene (**16**).* A solution of **15** (11.5 g) in acetic acid (30 ml) was refluxed for 5 min, cooled, neutralized with aqueous sodium hydroxide, and extracted with ether. The ether extract was weshed with brine, dried over sodium sulfate, and evaporated *in vacuo*. The residue was chromatographed on silica gel (100 g), using hexane-benzene (1:1) as the eluent, to give **16** (10.3 g: 95%); ^{1}H NMR: 0.96 (6H, s, -$\overset{|}{C}$(CH_3)$_2$), 1.19 (3H, s, C_{10}-CH_3), 2.06 (3H, s, C_{15}-CH_3), 3.73 (3H, s, -OCH_3), 4.96 (2H, bs, -$\overset{|}{C}$=CH_2), 6.61 (1H, s) and 6.72 (1H, s) (C_{11}-H and C_{14}-H).

*12-Methoxyabieta-8,11,13-trien-16-ol (**17**).* A solution of boron trifluoride etherate (2.4 ml) in dry tetrahydrofuran (4.0 ml) was added dropwise at −5—0 °C to a stirred mixture of **16** (4.0 g) and sodium borohydride (530 mg) in dry tetrahydrofuran (35 ml) in a stream of nitrogen. After the mixture had been stirred at 0—5 °C for 2 h, there were added successively aqueous tetrahydrofuran (50%: 6.0 ml), aqueous sodium hydroxide (12%: 6.3 ml), and hydrogen peroxide (30%: 6.3 ml) at −5—0°C. The mixture was stirred at −5—0 °C for 30 min and then at room temperature for 1 h, diluted with water, and extracted with ether. The ether extract was washed with brine, dried over sodium sulfate, and evaporated *in vacuo*. The residue was chromatographed on silica gel (200 g), using benzene as the eluent, to give a mixture of C-15 epimers (**17**) (2.9 g: 70%); IR: 3592, 3456 cm^{-1}; ^{1}H NMR: 0.96 (6H, s, -$\overset{|}{C}$(CH_3)$_2$), 1.16 (3H, bd, J=7 Hz, C_{15}-CH_3), 1.17 (3H, s, C_{10}-CH_3), 1.52 (1H, s, -OH), 3.22 (1H, m, C_{15}-H), 3.46 (2H, bs, -$C\underline{H}_2$OH), 3.74 (3H, s, -OCH_3), 6.59 (1H, s) and 6.67 (1H, s) (C_{11}-H and C_{14}-H).

*16-Acetoxy-12-methoxyabieta-8,11,13-triene (**18**).* A mixture of **17** (1.2 g), acetic anhydride (2.0 ml), and pyridine (5.0 ml) was stirred at 80—85 °C for 1.5 h. After the usual work-up, the crude product was purified by column chromatography on silica gel (50 g), using benzene as the eluent, to give **18** (1.3 g: 94%); IR: 1725 cm^{-1}; ^{1}H NMR: 0.97 (6H, s, -$\overset{|}{C}$(CH_3)$_2$), 1.19 (3H, s, C_{10}-CH_3), 1.20 (3H, d, J=7 Hz, C_{15}-CH_3), 1.97 (3H, s, -$OCOCH_3$), 3.78 (3H, s, -OCH_3), 4.05 (2H, bd, J=7 Hz, -CH_2O-), 6.63 (1H, s) and 6.70 (1H, s) (C_{11}-H and C_{14}-H).

*16-Acetoxyabieta-8,11,13-trien-12-ol (**19**).* A mixture of **18** (1.3 g), anhydrous aluminium chloride (2.9 g), and ethanethiol (2.7 ml) in dichloromethane (20 ml) was stirred at 0−5 °C for 5 min and then at room temperature for 1 h. The mixture was poured into dilute hydrochloric acid and extracted with ether. The ether extract was washed with brine, dried over sodium sulfate, and evaporated *in vacuo*. The residue was chromatographed on silica gel (50 g), using ether-benzene (1:99) as the eluent, to give **19** (1.1 g: 91%); IR: 3605, 3405, 1720 cm^{-1}; ^{1}H NMR: 0.95 (6H, s, -$\overset{|}{C}$(CH_3)$_2$), 1.13 (3H, s, C_{10}-CH_3), 1.26 (3H, d, J=7 Hz, C_{15}-CH_3), 2.05 (3H, s, -$OCOCH_3$), 3.8—4.4 (2H, m, -CH_2O-), 6.38 (1H, s, C_{12}-OH), 6.55 (1H, s) and 6.64 (1H, s) (C_{11}-H and C_{14}-H).

*16-Acetoxy-12-benzoyloxyabieta-8,11,13-trien-11-ol (**20**).* A solution of **19** (862 mg) and benzoyl perpxide (3.0 g) in chloroform (10 ml) was allowed to stand at room temperature for 50 h. The chloroform solution was diluted with ether. This ether solution, after addition of acetic acid (9.0 ml) and aqueous potassium iodide (30%: 30 ml), was stirred at room temperature for 4 h. The mixture was washed successively with water, aqueous sodium thiosulfate, aqueous sodium hydrogencarbonate, and brine. After being dried over sodium sulfate, the solvent was evaporated *in vacuo* and the residue was purified by column chromatography on silica gel (70 g), using benzene as the eluent, to give **20** (446 mg: 40%). IR: 3575, 3375, 1730 cm^{-1}; ^{1}H NMR: 0.97 (6H, s, -$\overset{|}{C}$(CH_3)$_2$), 1.15 (d, J=7 Hz) and 1.18 (d, J=7 Hz) (3H, C_{15}-CH_3), 1.34 (3H, s, C_{10}-CH_3), 1.86 (3H, s, -$OCOCH_3$), 3.93 (2H, m, -CH_2O-), 5.65 (1H, s, C_{11}-OH), 6.45 (1H, s, C_{14}-H), 7.30—7.65(m) and 8.00—8.30(m) (5H, -C_6H_5).

*11,12,16-Triacetoxyabieta-8,11,13-triene (**21**).* A stirred mixture of **20** (327 mg) and lithium aluminium hydride (60 mg) in dry ether (7.0 ml) was refluxed for 2 h. The mixture was poured into ice-dilute hydrochloric acid and extracted with ether. The ether extract was washed with brine, dried over sodium sulfate, and evaporated *in vacuo* to give the crude triol (289 mg).

The crude triol (289 mg) was acetylated with acetic anhydride (1.0 ml) in pyridine (1.0 ml) at room temperature for 17 h. After the usual work-up, the crude product was purified by column chromatography on silica gel (15 g), using ether-benzene (3:97) as the eluent, to give **21** (290 mg: 90%). IR: 1761, 1731 cm^{-1}; ^{1}H NMR: 0.95 (6H, s,

$-\overset{|}{C}(CH_3)_2$), 1.20 (3H, bd, $J=7$ Hz, C_{15}-CH_3), 1.22 (3H, s, C_{10}-CH_3), 1.95 (3H, s, C_{16}-$OCOCH_3$), 2.22 (6H, s, C_{11}-$OCOCH_3$ and C_{12}-$OCOCH_3$), 3.97 (2H, bd, $J=7$ Hz, $-CH_2O-$), 6.77 (1H, s, C_{14}-H).

*11,12,16-Triacetoxyabieta-8,11,13-trien-7-one (**22**).* A mixture of **21** (340 mg) and chromium trioxide (120 mg) in acetic acid (5.0 ml) was stirred at 0—5 °C for 15 min and then at room temperature for 22 h. The mixture was diluted with water and extracted with ether. The ether extract was washed successively with aqueous sodium hydrogencarbonate and brine, dried over sodium sulfate, and evaporated *in vacuo*. The residue was chromatographed on silica gel (15 g), using ether-benzene (4:96) as the eluent, to give **22** (255 mg: 73%). IR: 1773, 1727, 1683, 1607 cm^{-1}; ^1H NMR ($CDCl_3$): 0.96 (3H, s) and 0.98 (3H, s) ($-\overset{|}{C}(CH_3)_2$), 1.24 (d, $J=7$ Hz) and 1.28 (d, $J=7$ Hz) (3H, C_{15}-CH_3), 1.35 (3H, s, C_{10}-CH_3), 2.03 (3H, s, C_{16}-$OCOCH_3$), 2.35 (6H, s, C_{11}-$OCOCH_3$ and C_{12}-$OCOCH_3$), 4.06 (d, $J=7$ Hz) and 4.09 (d, $J=7$ Hz) (2H, $-CH_2O-$), 8.03 (1H, s, C_{14}-H).

*7,11,12,16-Tetraacetoxyabieta-6,8,11,13-tetraene (**23**).* A mixture of **22** (112 mg) and *p*-toluenesulfonic acid monohydrate (10 mg) in isopropenyl acetate (2.0 ml) was refluxed for 14 h. The mixture was cooled and diluted with ether. The ether solution was washed with brine, dried over sodium sulfate, and evaporated *in vacuo* to give the crude **23** (139 mg) which, without purification, was used in the next reaction. ^1H NMR: 0.97 (3H, s) and 1.05 (3H, s) ($-\overset{|}{C}(CH_3)_2$), 1.25 (3H, s, C_{10}-CH_3), 5.61 (1H, d, $J=2.5$ Hz, C_6-H), 6.95 (1H, s, C_{14}-H).

*6α,11,12,16-Tetraacetoxyabieta-8,11,13-trien-7-one (**24**).* A mixture of the crude **23** (139 mg) and *m*-chloroperbenzoic acid (85%: 58 mg) in dichloromethane (3.0 ml) was stirred at 0—5 °C for 10 min and then at room temperature for 24 h. The mixture was diluted with ether and washed successively with aqueous potassium iodide, aqueous sodium thiosulfate, aqueous sodium hydrogencarbonate, and brine. After being dried over sodium sulfate, the ether solution was evaporated *in vacuo* to give a mixture of 6α-acetoxy and 6α-hydroxy derivatives (147 mg), which was immediately acetylated with acetic anhydride (1.0 ml) in pyridine (1.0 ml) at room temperature for 20 h. After the usual work-up, the crude product was chromatographed on silica gel (5.0 g). Elution with ether-benzene (5:95) gave **24** (101 mg: 86% from **22**); IR: 1774, 1734, 1700, 1607 cm^{-1}; ^1H NMR ($CDCl_3$: 90 MHz): 1.07 (3H, s) and 1.14 (3H, s) ($-\overset{|}{C}(CH_3)_2$), 1.25 (3H, d, $J=7$ Hz, C_{15}-CH_3), 1.52 (3H, s, C_{10}-CH_3), 2.00 (3H, s, C_{16}-$OCOCH_3$), 2.23 (1H, d, $J=14$ Hz, $C_{5\alpha}$-H), 2.24 (3H, s) and 2.31 (6H, s) (C_6-$OCOCH_3$, C_{11}-$OCOCH_3$, and C_{12}-$OCOCH_3$), 3.1—3.5 (1H, m, C_{15}-H), 4.05 (d, $J=7$ Hz) and 4.08 (d, $J=7$ Hz) (2H, $-CH_2O-$), 5.83 (1H, d, $J=14$ Hz, $C_{6\beta}$-H), 7.99 (1H, s, C_{14}-H). The ^1H NMR spectrum of **24** was in good agreement with that of natural nellionol tetraacetate,[1] except for the signals due to the corresponding C-15 epimer. Found: C, 65.14; H, 7.11%. Calcd for $C_{28}H_{36}O_9$: C, 65.10; H, 7.02%.

*6α,11,12,16-Tetrahydroxyabieta-8,11,13-trien-7-one (**12**).* A mixture of **24** (83 mg) and dilute hydrochloric acid (10%: 0.5 ml) in ethanol (2.0 ml) was refluxed for 3 h. The mixture was cooled, diluted with water, and extracted with ether. The ether extract was washed with brine, dried over sodium sulfate, and evaporated *in vacuo*. The residue was chromatographed on silicic acid (Mallinckrodt CC-4: 4.0 g), using hexane-chloroform (1:4) as the eluent, to give **12** (32 mg: 55%). IR: 3492, 3400—3050, 1663, 1608 cm^{-1}; ^1H NMR (DMSO-d_6: 90 MHz): 1.16 (3H, s) and 1.18 (3H, s) ($-\overset{|}{C}(CH_3)_2$), 1.18 (3H, d, $J=6$ Hz, C_{15}-CH_3), 1.48 (3H, s, C_{10}-CH_3), 1.68 (1H, bd, $J=12$ Hz, $C_{5\alpha}$-H), 3.55 (2H, bd, $J=6$ Hz, $-CH_2O-$), 4.47 (1H, bd, $J=12$ Hz, $C_{6\beta}$-H), 7.33 (1H, s, C_{14}-H). The ^1H NMR spectrum of **12** was in good agreement with that of natural nellionol,[1] except for the signals due to the corresponding C-15 epimer.

*11,12,16-Triacetoxyabieta-6,8,11,13-tetraene (**25**).* A mixture of **22** (167 mg) and sodium borohydride (30 mg) in methanol (3.0 ml) was stirred at 0—5 °C for 30 min and then at room temperature for 1 h. The mixture was acidified with dilute hydrochloric acid (10%: 0.5 ml) refluxed for 1 h, and evaporated *in vacuo*. The residue was extracted with ether. The ether extract was washed with brine, dried over sodium sulfate, and evaporated *in vacuo*. The residual oil was acetylated[12] with acetic anhydride (1.0 ml) in pyridine (1.0 ml) at 60—70 °C for 3 h to give the crude **25** (160 mg) which, without purification, was used in the next reaction. IR: 1765, 1730 cm^{-1}; ^1H NMR: 0.96 (3H, s) and 1.03 (3H, s) ($-\overset{|}{C}(CH_3)_2$), 1.11 (3H, s, C_{10}-CH_3), 1.18 (d, $J=7$ Hz) and 1.23 (d, $J=7$ Hz) (3H, C_{15}-CH_3), 1.95 (3H, s, C_{16}-$OCOCH_3$), 2.20(3H, s) and 2.23 (3H, s) (C_{11}-$OCOCH_3$ and C_{12}-$OCOCH_3$), 3.93 (d, $J=7$ Hz) and 4.00 (d, $J=7$ Hz) (2H, $-CH_2O-$), 5.93 (1H, dd, $J=9$ and 3 Hz, C_6-H), 6.45 (1H, dd, $J=9$ and 3 Hz, C_7-H), 6.77 (1H, s, C_{14}-H).

*11,12,16-Triacetoxyabieta-8,11,13-trien-6-one (**26**).* A mixture of the crude **25** (160 mg) and *m*-chloroperbenzoic acid (85%: 180 mg) in dichloromethane (4.0 ml) was stirred at 0—5 °C for 1 h and then at room temperature for 14 h. The mixture was diluted with ether and washed successively with aqueous potassium iodide, aqueous sodium thiosulfate aqueous sodium hydrogencarbonate, and brine. The ether solution was dried over sodium sulfate and evaporated *in vacuo*. The residual oil was refluxed with dilute hydrochloric acid (10%: 0.5 ml) in methanol (4.0 ml) for 1 h. The mixture was evaporated *in vacuo*, diluted with water, and extracted with ether. The ether extract was washed with water, dried over sodium sulfate, and evaporated *in vacuo* to give an oil (155 mg). This oil was acetylated[12] with acetic anhydride (0.5 ml) in pyridine (0.5 ml) at 75—85 °C for 3 h. After the usual work-up, the crude product was purified by column chromatography on silica gel (7.0 g), using ether-benzene (3:97) as the eluent, to give **26** (64 mg: 40% from **22**). IR: 1767, 1733, 1720 cm^{-1}; ^1H NMR ($CDCl_3$): 1.05 (3H, s) and 1.23 (3H, s) ($-\overset{|}{C}(CH_3)_2$), 1.22 (d, $J=7$ Hz) and 1.24 (d, $J=7$ Hz) (3H, C_{15}-CH_3), 1.34 (3H, s, C_{10}-CH_3), 2.05 (3H, s, C_{16}-$OCOCH_3$), 2.34 (6H, s, C_{11}-$OCOCH_3$ and C_{12}-$OCOCH_3$), 2.60 (1H, bs, C_5-H), 3.64 (2H, br, $-COCH_2-$), 4.06 (d, $J=7$ Hz) and 4.09 (d, $J=7$ Hz) (2H, $-CH_2O-$), 6.90 (1H, s, C_{14}-H).

*6,11,12,16-Tetraacetoxyabieta-5,8,11,13-tetraen-7-one (**27**).* A solution of **26** (84 mg) in acetone (2.0 ml) was oxidized with Jones reagent [2.5 M (1 M = 1 mol dm^{-3}): 0.1 ml] at 0—5 °C for 10 min and then at room temperature for 2 h. The mixture was diluted with water and extracted with ether. The ether extract was washed with brine, dried over sodium sulfate, and evaporated *in vacuo*. The residual oil (78 mg) was refluxed with acetic anhydride (4.0 ml) in the presence of anhydrous sodium acetate (200 mg) for 2.5 h with stirring. The mixture was diluted with water and benzene, evaporated *in vacuo*, and extracted with ether. The ether extract was washed successively with aqueous sodium hydrogencarbonate and brine, dried over sodium sulfate, and evaporated *in vacuo*. The residue was chromatographed on silica gel (4.0 g), using ether-benzene (5:95) at the eluent, to give **27** (49 mg: 52%). IR: 1776, 1728, 1658, 1612 cm^{-1}; ^1H NMR ($CDCl_3$: 90 MHz): 1.29 (d, $J=$

7 Hz) and 1.31 (d, $J=7$ Hz) (3H, C_{15}-CH_3), 1.40 (6H, s, -$\dot{C}(CH_3)_2$), 1.65 (3H, s, C_{10}-CH_3), 2.00(s) and 2.01(s) (3H, C_{16}-$OCOCH_3$), 2.32 (3H, s) and 2.36 (6H, s) (C_6-$OCOCH_3$, C_{11}-$OCOCH_3$, and C_{12}-$OCOCH_3$), 3.24 (1H, m, C_{15}-H), 4.07 (d, $J=7$ Hz) and 4.10 (d, $J=7$ Hz) (2H, -CH_2O-), 8.11 (1H, s, C_{14}-H). The ^{1}H NMR spectrum of **27** was in good agreement with that of natural dehydronellionol tetraacetate,[1] except for the signals due to the corresponding C-15 epimer. Found: C, 65.06; H, 6.74%. Calcd for $C_{28}H_{34}O_9$: C, 65.36; H, 6.66%.

*6,11,12,16-Tetrahydroxyabieta-5,8,11,13-tetraen-7-one (**13**).* A mixture of **27** (35 mg) and dilute hydrochloric acid (10%: 0.3 ml) in methanol (2.0 ml) was refluxed for 1 h. The mixture was diluted with water and extracted with ether. The ether extract was washed with brine, dried over sodium sulfate, and evaporated *in vacuo*. The residue was chromatographed on silicic acid (Mallinckrodt CC-4: 3.0 g), using hexane-chloroform (1:4) as the eluent, to give **13** (8.9 mg: 38%). IR: 3515, 3450—3050, 1630, 1600 cm^{-1}; ^{1}H NMR ($CDCl_3$: 90 MHz): 1.38 (3H, d, $J=7$ Hz, C_{15}-CH_3), 1.46 (6H, s, -$\dot{C}(CH_3)_2$), 1.67 (3H, s, C_{10}-CH_3), 3.70—4.14 (2H, m, -CH_2O-), 7.09 (1H, s, -OH), 7.59 (1H, s, C_{14}-H). The ^{1}H NMR spectrum of **13** was in good agreement with that of natural dehydronellionol,[1] except for the signal due to the corresponding C-15 epimer.

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