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COMPONENTS OF THE ROOT OF *LINDERA STRYCHNIFOLIA* VILL.—IX[1]

STRUCTURES OF LINDESTRENE AND LINDERENE ACETATE

K. TAKEDA, H. MINATO, M. ISHIKAWA and M. MIYAWAKI
Shionogi Research Laboratory, Shionogi & Co., Ltd., Fukushima-ku, Osaka, Japan

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Abstract—In addition to the four known sesquiterpenes (I–IV) two new ones have been isolated from the root of *Lindera strychnifolia* Vill. One of the new sesquiterpenes was named "lindestrene" and is represented by V, and another was shown to be an acetate of linderene (I).

AS REPORTED, linderene[2] (I), linderane[3] (II), linderalactone[1] (III) and isolinderalactone[1] (IV), all sesquiterpenes having a furan ring, were isolated from the root of *Lindera strychnifolia* Vill., and their structures have been established.

Since many sesquiterpenes with a γ-lactone function instead of a furan ring are being reported in the literature, the extract of the root of *Lindera strychnifolia* Vill. was further examined for sesquiterpene lactones, and consequently, two new ses-

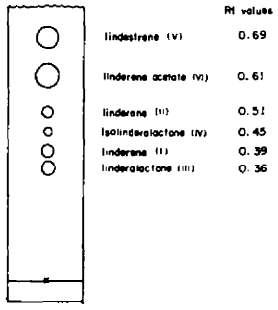


FIG. 1. Thinlayer chromatogram

quiterpenes were isolated. These two sesquiterpenes also have the furan ring and since sesquiterpene lactones do not occur in the same plant, we wish to report the results of structural investigations of these new compounds. After separation of the major portions of linderene (I) and linderane (II) by crystallization from the ether extract of the root, the residual mother liquor showed a thinlayer chromatogram as seen in Fig. 1. As the two large spots having R_f values of 0·69 and 0·61 suggested the presence of new sesquiterpenes, we isolated these two components (by distillation, alumina and preparative thinlayer chromatography) and named them respectively "lindestrene" (V) and "linderene acetate[2]" (VI).

[1] Part VIII: K. Takeda, H. Minato and M. Ishikawa, *J. Chem. Soc.* in the press.
[2] K. Takeda and M. Ikuta, *Tetrahedron Letters* No. 6, 277 (1964).
[3] K. Takeda, H. Minato and I. Horibe, *Tetrahedron* **19**, 2307 (1963).

Lindestrene (V), $C_{15}H_{18}O$, a colourless mobile unstable oil, b.p. 100–102°/2 mm, R_f value 0·69, $[\alpha]_D$ −63·4°, shows a positive Ehrlich's colour test and an absorption maximum at 218 mμ (ε 8040). From these facts and the data of the NMR spectrum [a methyl signal on a furan ring at 8·05 τ (doublet J — 1·1) and one furan ring proton at 2·96 τ (quartet J = 1·1)], it is assumed that lindestrene has a methylfurano[1–3] grouping in the molecule.

The IR spectrum (frequencies at 3076, 1655 and 885 cm^{-1}) and the NMR spectrum (two olefinic protons at 5·03 and 5·18 τ) show the presence of an exocyclic methylene group, which was confirmed by the liberation of formaldehyde on ozonolysis.

These results and the signals at 9·18 τ (an angular methyl group) and at 4·46 τ (singlet, two olefinic protons) in the NMR, establish lindestrene as a bicyclic sesquiterpene with two ethylenic double bonds and a furan ring.

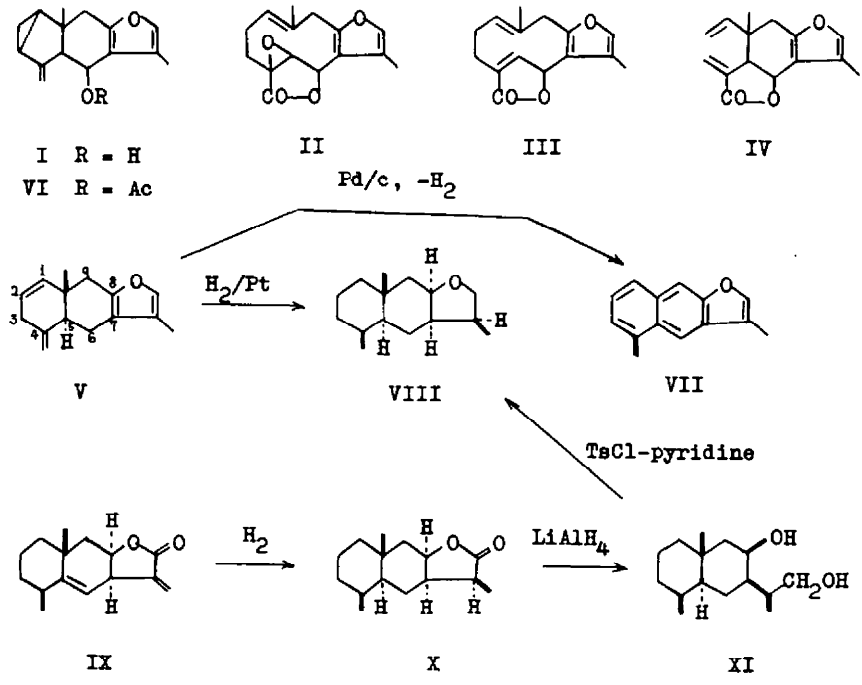


CHART 1

Dehydrogenation of lindestrene with 10% Pd–C, affords an aromatic compound with fourteen carbon atoms, m.p. 72–74°; which was shown by UV and the NMR spectra to be a naphthofuran and based on the structural study of lindestrene (V) to have the structure VII. On the other hand lindestrene (V) on hydrogenation in ethanol–acetic acid with Adams' catalyst, takes up 4 moles of hydrogen to give octahydrodehydroxylinderene (VIII)[2,4,5] m.p. 27°. As octahydrodehydroxylinderene was assumed to have structure VIII, the synthesis of this compound from alantolactone (IX) by Tanabe's method[6] confirms its structure.

[4] K. Takeda and T. Shimada, *Yakugaku Zasshi* **64**, 154 (1944).
[5] H. Hikino, Y. Hikino and I. Yoshioka, *Chem. Pharm. Bull., Japan* **10**, 641 (1962).
[6] K. Tanabe, *Chem. Pharm. Bull., Japan* **6**, 214 (1958).

The tetrahydrofuran derivative (VIII), obtained by lithium aluminium hydride reduction of tetrahydroalantolactone (X) followed by ring-closure of a diol (XI) with tosyl chloride–pyridine, is identical with octahydrodehydroxylinderene in all respects. Further as the stereochemistry[7] of tetrahydroalantolactone is represented by X, that of octahydrodehydroxylinderene must be represented by VIII.

Lindestrene, therefore, belongs to the eudesmane group of sesquiterpenes and has a furan ring at C7–8. The ethylenic double bond of an exocyclic methylene type should be situated at C-4. Moreover, as lindestrene (V) shows no absorption maximum in the UV except that ascribed to the isolated furano grouping, it is reasonable to suppose that the remaining ethylenic double bond is situated at the position isolated from the exocyclic double bond at C-4 or the methylfurano grouping, that is at Cl-2, although two olefinic protons of this double bond appear in the NMR as a singlet at 4·46 τ.

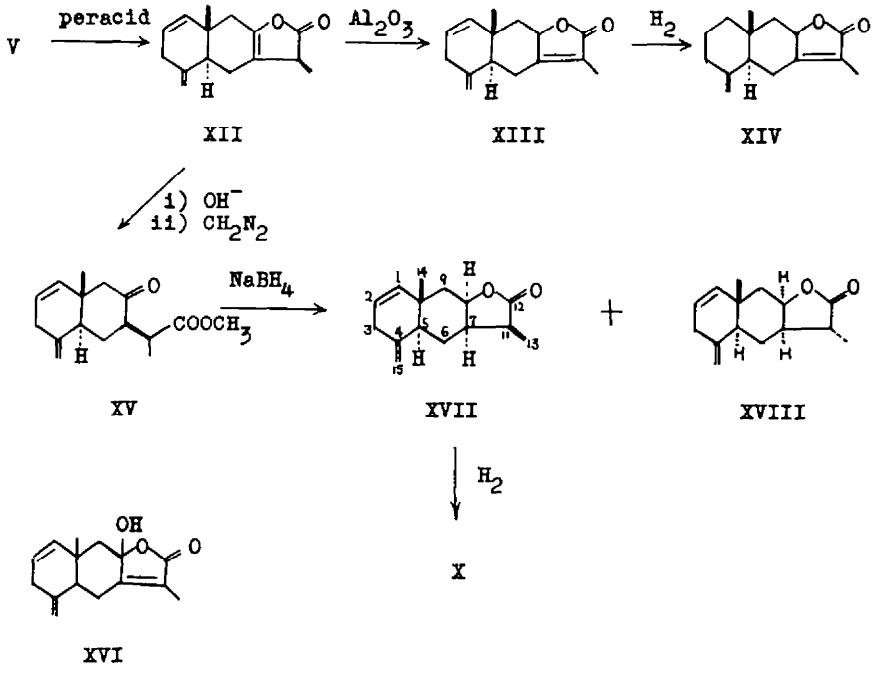


CHART 2

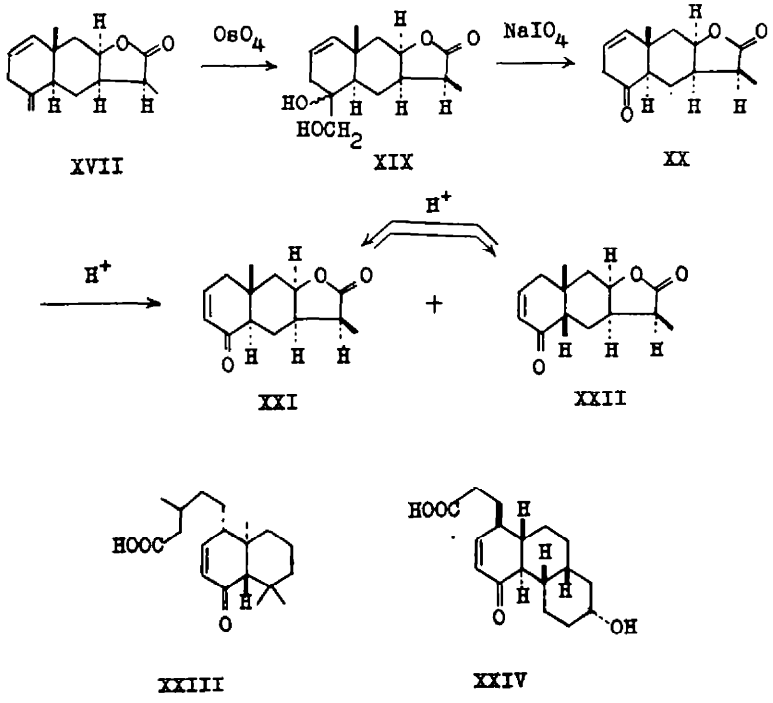
As the furano grouping in lindestrene (V) is unstable,* it was converted into the stable γ-lactonic function in order to confirm the position of the ethylenic double bond.

When lindestrene (V) is oxidized with 1·2 moles perbenzoic acid at 0°, an unstable oil is obtained. This compound was assumed to be an enol lactone (XII) by the frequency at 1790 cm^{-1} and affords by alumina chromatography an unstable oily α,β-unsaturated γ-lactone (XIII) [1752 and 1692 cm^{-1}, 220 mμ (ε 16,000)], which was hydrogenated with Raney Ni in 95% ethanol to give XIV, m.p. 112–114°. Since,

* When lindestrene is allowed to stand in air at room temp, it is rapidly autoxidized to give a resinous substance.

[7] W. Cocker and M. A. Nisbet, *J. Chem. Soc.* 534 (1963).

XIV was shown to be identical with an authentic sample[8]* by mixed melting point determination and comparison of IR spectra, no change in the molecular skeleton could have taken place during oxidation. The unstable oil (XII) was hydrolyzed in a nitrogen atmosphere and treated with diazomethane to give an oily ketoester (XV) and a small amount of XVI. The ketoester (XV) shows no absorption maximum in the UV above 210 mμ, and the IR spectrum shows all the bands ascribed to the exocyclic methylene group. The ketoester (XV), on sodium borohydride reduction, affords two γ-lactones, m.p. 149-151° (XVII) and m.p. 100–102° (XVIII). The former yields tetrahydroalantolactone (X) on hydrogenation with 5% Pd–$BaCO_3$, and the latter is converted into the former by refluxing with potassium carbonate[9] in tetralin. As it was established by Cocker and Nisbet[7] that the methyl group at C-11 in tetrahydroalantolactone (X) possesses the β-configuration, XVIII is a stereoisomer having an α-orientated methyl group at C-11. In this way, the furano grouping in lindestrene could be converted into the γ-lactonic function without changing the position of the ethylenic double bonds.



XVII XIX XX XXI XXII XXIII XXIV

CHART 3

Compound XVII, on oxidation with 1 mole osmium tetroxide, affords a dihydroxy derivative (XIX), m.p. 161–163°, the IR and NMR spectra of which show that all the characteristics ascribed to the exocyclic methylene group have been lost. Compound XIX, when oxidized with sodium periodate, yields a ketone (XX), m.p.

* The authors are very much indebted to Dr. I. Iwai (Sankyo Takamine Lab.) for sending them the sample of XIV.

[8] H. Matsumura, I. Iwai and E. Ohki, *Yakugaku Zasshi* 74, 1029 (1954); K. Tsuda, K. Tanabe, I. Iwai and K. Funakoshi, *J. Amer. Chem. Soc.* 79, 5721 (1957).

[9] W. Cocker, L. O. Hopkins, J. B. H. McMurry and M. A. Nisbet, *J. Chem. Soc.* 4721 (1961).

171–173°, which exhibits a frequency at 1717 cm^{-1} corresponding to an isolated six-membered ring ketone and multiplet signals at 3·92–4·58 τ due to two olefinic protons. As the ketone (XX) shows no absorption maximum above 210 mμ, the remaining double bond is not conjugated with the newly formed carbonyl group at C-4.

The ketone (XX), on treatment with 2·5% hydrochloric acid–methanol, affords an equilibrium mixture[10] (ca. 2:1·5) of two α,β-unsaturated ketones. The one ketone, present in greater amounts, was obtained as colourless needles* (XXI), m.p. 202–204° [1680 cm^{-1} and 227 mμ (ε 9200)] and the other as colourless needles

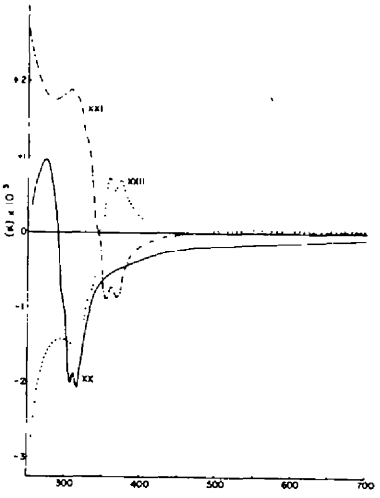


FIG. 2. Optical rotatory dispersion curves of XX, XXI and XXII

(XXII), m.p. 212–214° [1675 cm^{-1} and 230 mμ (ε 8500)]. Both ketones, as established by their spectral properties, are α,β-unsaturated and the double bond of either XXI or XXII should be situated at C2–3. Consequently, the position of the double bond in question is at Cl-2 in XX and lindestrene must be represented by structure V.

The stereochemistry of lindestrene is also established as A/B *trans* as shown in the formula V, since lindestrene affords octahydrodehydroxylinderene (VIII) on hydrogenation.

Compounds XX and XXI both show a negative Cotton effect, whereas XXII exhibits the opposite-sign on optical rotatory dispersion as shown in Fig. 2. It therefore follows that XX is a 5α(A/B-*trans*)-compound like the 4-keto-5α-steroids. Based on the Δ^2-4-keto system, according to Halsall and Moyle,[11] XXIII or XXIV exhibits a positive or negative Cotton effect, it may, therefore, be concluded that XXI is a 5α-(A/B-*trans*)-compound and XXII having an opposite sign Cotton effect is a 5β(A/B-*cis*)-compound. The 5β-compound could possess either the steroid or the

* Prof. Herz obtained an α,β-unsaturated ketone represented by XXI, m.p. 181–182°, ν_{max} 1680 cm^{-1} and λ_{max} 225 mμ (ε 8350), during the study of ivalin. (W. Herz and G. Högenauer, *J. Org. Chem.* **27**, 905 (1962).)

[10] W. Herz and S. Rajappa, *J. Org. Chem.* **28**, 227 (1963); F. Sondheimer and D. Rosenthal, *J. Amer. Chem. Soc.* **80**, 3995 (1958).

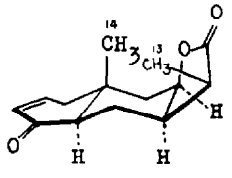
[11] T. G. Halsall and M. Moyle, *J. Chem. Soc.* 1324 (1960).

nonsteroid-like *cis*-conformation, as represented by XXVI or XXVII, respectively. In the following Table, the NMR spectral data of compounds XX, XXI and XXII are shown.

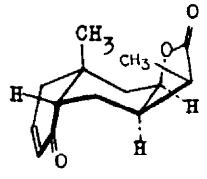
TABLE 1. NMR DATA (τ)

	XX	XXI	XXII
14–CH_3 group	9·07	9·02	8·74
13–CH_3 group	8·74	8·75	8·76
H at C–8	5·52	5·53	5·55

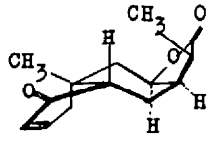
The signals of the 13-methyl group and the proton at C-8 appear at almost the same positions in XX, XXI and XXII. Either formula XXV or XXVI possesses an equatorial hydrogen at C-8 and both have similar sterical arrangements around the γ-lactone function. On the other hand, XXVII has an axial hydrogen at C-8 and exhibits steric interaction between the hydrogen at C-5 and the 13-methyl group. Therefore, if XXII is in the nonsteroid-like *cis*-conformation (XXVII), its NMR data must differ from that shown in the Table. Moreover, since both formula XXV and XXVII have the same conformation in the A-ring and the 1,3-diaxial interaction between the 14-methyl group and the lactonic oxygen at C-8 observed in XXV disappears in XXVII, the signal of the 14-angular methyl group in XXVII is not able to shift to a lower field in the NMR than in XXV. This is not the case, as the 14-methyl group of XXII appears at the lower field (8·74 τ). It may, therefore, be concluded that XXII is not in the nonsteroid-like *cis*-conformation (XXVII) but in the steroid-like *cis*-conformation (XXVI), in which the 14-methyl group is shifted to lower field by the anisotropy of the Δ^2-4-keto grouping.



XXV



XXVI



XXVII

CHART 4

Linderene acetate (VI), $C_{17}H_{20}O_3$, m.p. 79–82°, R_f value 0 61, $[\alpha]_D$ +25·7°, based on the NMR[2] and IR data, is assumed to be the acetate of linderene (I) and linderene acetate (VI) is hydrolized with 5% potassium hydroxide in methanol to linderene

(I) and acetic acid, which was confirmed by conversion to its benzylthiuronium salt. The structure of linderene acetate is therefore established.

EXPERIMENTAL

NMR spectra were taken on $CDCl_3$ solution with a Varian A-60 NMR Spectrometer. Optical rotatory dispersion measurements were performed in dioxan solution by means of a Rudolph Recording Spectropolarimeter, Model 260/655/850/810–614. M.ps were taken on a Kofler block and corrected. Unless otherwise stated, UV spectra were taken in 95% ethanol and rotations in dioxan. Thinlayer chromatography was carried out with "Merck", Kieselgel G and benzene–ethyl acetate (9:1).

Isolation of lindestrene (V) *and linderene acetate* (VI). The dried and sliced root of *Lindera strychnifolia* Vill. (3 kg) was extracted with ether (7L × 2) at room temp for 5 days. The combined ether solution was washed with 5% NaOH aq and water, dried (Na_2SO_4) and evaporated to about 200 ml *in vacuo* and after leaving in a N_2 atm overnight in an ice box, a crystalline substance (2·27 g), crude linderane (II) separated. The filtrate was evaporated *in vacuo* and light petroleum (30 ml) was added and after again leaving overnight in an ice box, a crystalline substance (5·9 g), crude linderene (I) separated. The mother liquor was evaporated *in vacuo* leaving a reddish-brown oil (52·1 g). The residue (44·3 g) was dissolved in light petroleum (500 ml) and chromatographed on neutral alumina (440 g). Elution with light petroleum afforded an yellow mobile oil (A, 5·9 g) and a yellow viscous oil (B, 13·0 g). Further elution afforded linderane (II), isolinderalactone (IV), linderalactone (III) and linderene (I) as reported in the preceding paper.[1] Fraction A was distilled at 90–106°/0·5 mm to give a pale yellow mobile oil (5·1 g), which was purified by preparative gas chromatography* giving a colourless oil (1·62 g). This oil was passed through alumina column and distilled to give lindestrene (V, 1·3 g), a colourless mobile oil, b.p. 100–102°/2 mm, $[\alpha]_D^{24\cdot5}$ −63·4° (±2°) (*c*, 0·835), R_f value 0·69, retention time 10·25 min,* λ_{max} 218 mμ (ε 8040), ν_{max}^{film} 3076, 1655, 1569 and 885 cm^{-1} (Found: C, 84·13; H, 8·56. $C_{15}H_{18}O$ requires: C, 84·07; H, 8·47%). Fraction B was rechromatographed on neutral alumina to give a colourless viscous oil (4·6 g), which was crystallized from light petroleum giving linderene acetate (VI), colourless prisms, m.p. 79–82°, $[\alpha]_D^{25\cdot5}$ +25·7° (±2°) (*c*, 1·168, ethanol), R_f value 0·61, ν_{max}^{nujol} 3070, 1727, 1664, 1624, 1560 and 885 cm^{-1} (Found: C, 75·13; H, 7·52. $C_{17}H_{20}O_2$ requires: 74·97; H, 7·40%).

Dehydrogenation of lindestrene (V). A mixture of lindestrene (V, 60 mg) and 10% Pd–C (60 mg) was heated at 300–310° for 5 min and then extracted with light petroleum. The extract was evaporated leaving a light yellow oil (41 mg), which gave the picric acid adduct of VII (27 mg) as reddish-brown prisms (from ethanol), m.p. 110–112° (Found: C, 57·57; H, 3·69. $C_{21}H_{17}O_8N_3$ requires: C, 57·40; H, 3·90%). The adduct was dissolved in ether and chromatographed on alumina to give VII, colourless prisms (from ethanol), m.p. 72–74°, λ_{max} 240 mμ (ε 61,200), 244 (60,300), 303 (6,980), 315 (10,500), 330 (8,360) and 336 (5,670), NMR 7·25 τ (CH_3—) and 7·65 τ (CH_3—, doublet J = 1·1 c/s) (Found: C, 85·91; H, 6·42. $C_{14}H_{12}O$ requires: C, 85·68; H, 6·71%). 2,4,6-Trinitrobenzene adduct of VII was obtained as orange needles, m.p. 140–142°.

Hydrogenation of lindestrene (V). A mixture of Adams' catalyst (40 mg) and lindestrene (V, 200 mg) in 90% ethanol (10 ml) and acetic acid (5 ml) was hydrogenated at room temp. After 4·0 moles H_2 had been absorbed, the reaction stopped, and the catalyst and the solvent were removed giving a neutral oil (198 mg), which was chromatographed on neutral alumina (12 g) to give octahydrodehydroxylinderene (VIII, 120 mg) as a colourless oil, b.p. 120°/0·5 mm (bath temp), colourless needles (from light petroleum), m.p. 26–27°, $[\alpha]_D^{22}$ −35·5° (±2°) (*c*, 1·046). (Found: C, 81·38; H, 11·84. $C_{15}H_{26}O$ requires: C, 81·02; H, 11·79%).

Conversion of lindestrene (V) *into* XIV. A solution of perbenzoic acid in benzene (3·7 ml, 1·1 equiv; 38 mg/ml) was added to a solution of lindestrene (V, 200 mg) in benzene (1 ml) in an ice bath and left for 13 hr at 0°. The solution was washed with 3N NaOH and water, dried (Na_2SO_4) and leaving a colourless oil (XII, 195 mg), ν_{max}^{film} 1790 cm^{-1}, which was chromatographed on neutral alumina (6 g) giving a colourless oil (XIII, 60·4 mg), ν_{max}^{film} 3084, 1752, 1692, 1656, and 887 cm^{-1}, λ_{max} 220 mμ (ε 16,000). This compound (XIII, 121 mg) was hydrogenated with Raney Ni (W–2, 0·1 ml) in ethanol (10 ml) and chromatographed on neutral alumina (3·6 g) to give XIV (94 mg),

* For separation of indestrene, a Yananimoto Gas Chromatograph GCG-3D was used, and a column, 3 m × 14 mm, consisting of Silicone 550 on chromosorb (30 to 60 mesh) was operated at 200° with a flow rate of 300 ml/min H_2.

colourless prisms, m.p. 112–114° (from light petroleum–ether), identical with an authentic sample by IR and mixed m.p.

Conversion of lindestrene (V) *into* XV. Lindestrene (V, 1·0 g) was oxidized with perbenzoic acid as described above to give crude XII (1·1 g), which was hydrolyzed with 5% KOH in methanol (20 ml) in a N_2 atm giving a neutral fraction (440 mg) and an acid fraction (660 mg). The acid fraction was esterified with diazomethane and chromatographed on silica gel (20 g) giving a colourless oil (XV, 410 mg), b.p. 107–110°/1 mm, ν_{max}^{film} 3088, 1735, 1715, 1658 and 890 cm^{-1}. (Found: C, 73·08; H, 8·69. $C_{15}H_{22}O_3$ requires: C, 73·25; H, 8·45%) and the product (XVI, 12 mg), colourless prisms, m.p. 210° (dec) (from methanol), $[\alpha]_D^{24.5}$ +202·5° (±2°) (*c*, 1·032), λ_{max} 216 mμ (ε 11,800), $\nu_{max}^{CHCl_3}$ 3326, 1753, 1655 and 891 cm^{-1}. (Found: C, 73·26; H, 7·52. $C_{15}H_{18}O_3$ requires: C, 73·14; H, 7·37%).

Reduction of XV *with sodium borohydride.* Sodium borohydride (44 mg) was added to a solution of XV (300 mg) in methanol (3 ml) in an ice bath and left for 2 hr at room temp. The solution was evaporated *in vacuo*, and the residue was extracted with ether. The extract was washed with water, dried (Na_2SO_4) and evaporated leaving a colourless oil (264 mg), which was crystallized from acetone to give XVII (28 mg), colourless plates, m.p. 149–151°, $[\alpha]_D^{24}$ −50·4° (±4°) (*c*, 0·546), $\nu_{max}^{CCl_4}$ 3088, 3012, 1780, 1655 and 892 cm^{-1} (Found: C, 77·69; H, 8·74. $C_{15}H_{20}O_3$ requires: C, 77·55; H, 8·62%). The mother liquor was chromatographed on neutral alumina giving XVIII (eluted first), colourless needles (12 mg). m.p. 100–102°, $\nu_{max}^{CCl_4}$ 1778, 1653 and 887 cm^{-1} (Found: C, 77·59; H, 8·66. $C_{15}H_{20}O_2$ requires: C, 77·55; H, 8·62%) and XVII (40 mg).

Isomerization of XVIII *into* XVII. A mixture of XVIII (31 mg) and anhydrous K_2CO_3 (30 mg) in tetralin (3 ml) was refluxed for 4 hr and evaporated *in vacuo*. The residue was extracted with ether, washed with water, dried (Na_2SO_4), evaporated and chromatographed on alumina to give XVII (4 mg), m.p. 148–150°, and a mixture (16 mg) of XVII and XVIII.

Hydrogenation of XVII. A mixture of XVII (16 mg) and 5% Pd—$BaCO_3$ (50 mg) in ethanol (10 ml) was catalytically hydrogenated to give tetrahydroalantolactone (X, 16 mg), m.p. 142–145°.

Oxidation of XVII *with osmium teroxide.* A solution of O_5O_4 (110 mg) in dry benzene (5 ml) was added to a solution of XVII (100 mg) in dry benzene (5 ml) in an ice bath and left for 40 hr at room temp. The mixture was saturated with H_2S and filtered. The filtrate was evaporated *in vacuo* leaving a crystalline substance (88·6 mg), which was recrystallized from acetone to give XIX (61·7 mg), colourless plates, m.p. 161–163°, $[\alpha]_D^{24}$ −94·3° (±4°) (*c*, 0·505) (Found: C, 67·50; H, 8·27. $C_{15}H_{22}O_4$ requires: C, 67·64; H, 8·33%).

Oxidation of XIX *with sodium periodate.* A solution of XIX (89 mg) and $NaIO_4$ (144 mg) in methanol (8 ml) and water (4 ml) was left overnight at room temp and evaporated *in vacuo*. The residue was dissolved in ether, washed with water, dried (Na_2SO_4) and evaporated leaving a crystalline substance (83 mg), which was recrystallized from acetone to give XX (74 mg), colourless prisms, m.p. 171–173°, $[\alpha]_D^{24}$ −115·2° (±4°) (*c*, 0·525), λ_{max} 281 mμ (ε 28), ν_{max}^{Nujol} 3021, 1761, 1712 and 741 cm^{-1} (Found: C, 71·69; H, 7·71. $C_{14}H_{18}O_3$ requires: C, 71·77; H, 7·74%). O.R.D. of XX (Fig. 2): $[\alpha]_{315.5}$ −2073°, $[\alpha]_{310.5}$ −1880°, $[\alpha]_{306.5}$ −2008°, $[\alpha]_{273}$ +945° (*c*, 0·525).

α,β-Unsaturated ketone derivatives (XXI *and* XXII). A solution of XX (64·2 mg) in 4N HCl (0·7 ml) and methanol (3 ml) was refluxed for 30 min and evaporated. The residue was dissolved in ether, washed with 2N Na_2CO_3 and water, dried (Na_2SO_4) and evaporated leaving a crystalline substance (63·9 mg). a mixture of XXI and XXII, which was separated into XXI (20 mg), colourless needles, (from ethyl acetate), m.p. 202–204°, $[\alpha]_D^{25}$ +18·8° (±2°) (*c*, 1·027), λ_{max} 227 mμ (ε 9200), $\nu_{max}^{CHCl_3}$ 1762 and 1680 cm^{-1}, R_f value 0·48 (Found: C, 71·46; H, 7·99. $C_{14}H_{18}O_3$ requires: C 71·77; H, 7·74%) and XXII (16 mg), colourless needles (from ethyl acetate), m.p. 212–214°, $[\alpha]_D^{25}$ +3·0° (±2°) (*c*, 0·804), λ_{max} 230 mμ (ε 8500), $\nu_{max}^{CHCl_3}$ 1762 and 1675 cm^{-1}, R_f value 0·62 (Found: C, 71·59; H, 8·15. $C_{14}H_{18}O_3$ requires: C, 71·77; H, 7·74%), by preparative thinlayer chromatography ("Merck" Kiesel Gel G, ethyl acetate–ether (1:1)) and recrystallization. O.R.D. of XXI (Fig. 2): $[\alpha]_{368.5}$ −873°, $[\alpha]_{361}$ −729°, $[\alpha]_{354}$ −889°, $[\alpha]_{345}$ −77·9°, $[\alpha]_{340}$ −97·4°, $[\alpha]_{330}$ +1129°, $[\alpha]_{325}$ +1276°, $[\alpha]_{315}$ +1795°, $[\alpha]_{310}$ +1846°, $[\alpha]_{306.5}$ +1898°, $[\alpha]_{294}$ +1765° (*c*, 1·027). O.R.D. of XXII (Fig. 2): $[\alpha]_{378}$ +687°, $[\alpha]_{365}$ +562°, $[\alpha]_{358.5}$ +716°, $[\alpha]_{349}$ +100°, $[\alpha]_{343}$ −39·8°, $[\alpha]_{334}$ −801°, $[\alpha]_{327}$ −1020°, $[\alpha]_{320}$ −1368°, $[\alpha]_{316}$ −1420°, $[\alpha]_{308}$ −1497°, $[\alpha]_{302}$ −1433° (*c*, 0·804).

An equilibrium mixture of XXI *and* XXII. A solution of XXI or XXII (1 mg) in 2·5% HCl–methanol (1 ml) was refluxed for 30 min and extracted with ether as described above. The residue was shown to be a mixture of XXI and XXII (ca. 2:1·5) by thinlayer chromatogram.

Hydrolysis of linderene acetate (VI). A solution of linderene acetate (VI, 100 mg) in 5% KOH

in methanol (1 ml) was refluxed for 1 hr in a N_2 atm and evaporated. The residue was dissolved in water and extracted with ether. The ether extract gave linderene (I, 80 mg). The aqueous layer was neutralized with 2N H_2SO_4, evaporated and extracted with methanol. The methanol extract was evaporated and dissolved in 50% ethanol (1 ml). To this solution were added one drop of 2N HCl and a solution of s-benzylthiuronium chloride (90 mg, 1·2 equiv) in 95% ethanol (0·5 ml). The crystalline substance (68 mg), m.p. 133–134°, was soon separated from this solution and shown to be identical with an authentic sample of s-benzylthiuronium acetate.

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