Dehydrogenation of Lindenenyl Acetate by Palladium

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Dehydrogenation of lindenenyl acetate (Ib) by palladium was studied. The reaction was found to proceed directly to a final product (linderazulene (II)) by a main route, and partly to II via a dihydroazulene intermediate (IV), by a concerted mechanism. Dehydrogenation of Ib in deuteropentane showed that palladium has properties of both a dehydrogenation and a hydrogenation catalyst under N₂, at 300°C.

About thirty years ago, we reported that lindenenol (Ia), a component of the root of lindera strychnifolia vill, was easily dehydrogenated with selenium, palladium or zinc to give linderazulene (II).2)

The mechanism of the ring reorganization involved in dehydrogenation of lindenenyl acetate (Ib) under mild conditions seemed particularly interesting; in an attempt to clarify this we have studied the reaction using a palladium metal catalyst.

In a previous study of the dehydrogenation reaction of the monoterpene3) gas chromatography with a thermal conductivity detector for analysis was used; as this required several milligrams of sample, in the present work we used a gas chromatograph equipped with a high sensitive flame ionization detector, thereby decreasing the sample required one hundredfold.

The palladium catalyst used was supported on barium carbonate, since lindenenyl acetate is very sensitive to acid. The catalyst (25 mm × 4 mm φ) was inserted into the flash heater block of the gas chromatograph, and connected to the column used to separate the reaction products. The performance in dehydrogenation by the catalyst, so combined with a gas chromatograph, was checked under mild conditions (injection block: 285°C, flow rate: 50 ml/min) and found to be unsatisfactory because of peak tailing. The application of cholesterol was found to markedly improve peak shape and minimize tailing.

Preliminary experiments using the above catalyst were made to trace the intermediates in the course of the dehydrogenation of lindenenyl acetate (Ib) to linderazulene (II). The results are shown in Fig. 1, with the Kováts index4) obtained on a carbowax column, and with molecular weights determined by GC-MS for each peak.

The peak (III) (M⁺: 212) which appeared under mild conditions a) (170°C, 50 ml/min) seems to be the first intermediate. Under these conditions conversion of Ib to linderazulene (II) was poor. Four major peaks (M⁺: 212, 214) appeared in addition to peak (III) under moderate

1) Location: Fukushima-ku, Osaka.
conditions b) (220°, 10 ml/min), and the azulene (II) yield increased. At 300° peaks (IV and V) (M⁺: 214) were characteristically increased together with the azulene (II) yield.

The fraction corresponding to the first peak in Fig. 1b showed M⁺: 214, but the NMR spectrum showed it to be a mixture; further purification was not possible owing to insufficient sample.

The second peak (V) in Fig. 1b was determined as lindenene by comparison of the NMR, IR, GC, and GC-MS data with those of an authentic sample.

Compound (VI), the third peak in Fig. 1b, has a molecular weight 212. The UV absorption at 272, 281, 285, and 291 μ suggests the existence of an extended conjugation of benzofuran. IR bands at 899 and 787 cm⁻¹ indicate a terminal methylene group. The NMR spectrum show in Fig. 2 suggests a H=C-H moiety. From these data the compound was at first tentatively assumed to be VI'. However, further examination by proton spin decoupling and nuclear Overhauser effect at 100 Mcps field led to a reassignment of the structure to VI. The results are shown in Fig. 2 and Fig. 3, respectively.

The four vinyl protons spread over ca. 5-4 τ collapsed to single patterns on irradiation at the C₄' methyl proton frequency. From a consideration of the coupling constant these signals can reasonably be assumed to result from a H₂ system. It can be seen that the C₄ proton is flanked by C₃ and C₄' methyl groups from the enhancement by the nuclear Overhauser effect, as shown in Fig. 3. Likewise, the C₄' proton may be orientated cis to the C₄' methyl group. The multiplet at 2.70 τ collapsed to a doublet (J=0.6 cps) and showed 28% enhancement by the NOE on irradiation at the C₆ methyl proton frequency, but was not effected by C₄' methyl.

6) This compound proved to be identical with the “benzofuran compound” reported previously (H. Ishii, M. Nakamura, T. Tozyo, and K. Takeda, Phytochemistry, 8, 2189 (1970) by comparison of their IR, UV, and NMR spectra.
protons. The coupling constant (0.6 cps) can be reasonably ascribed to a proton at the para position of a benzene ring. Therefore, the proton observed at 2.70 \( \tau \) should be placed at the C\(_7\) position. From the results of the NOE on C\(_6\)' and C\(_4\) protons by C\(_1\)' methyl protons, the butadiene moiety should be placed at the C\(_3\) position of benzo[furan]. From the above observations, the third peak (VI) on the gas chromatogram in Fig. 1b may be assigned to 3,6-dimethyl-5-[1'-methyl-but-1'-3'-dietyl]-benzo[furan] rather than VI'. Catalytic hydrogenation of compound (VI) by palladium consumed one mole equivalent of hydrogen to give the dihydro-compound(VII), which retains the three aromatic ring protons and one vinyl proton in the NMR spectrum. Reduction of the dihydro-compound (VII) to the tetrahydro-compound (VIII) by rhodium-platinum catalyst was slow; it gave a mixture, which was subjected to GC-MS. The molecular ion peak of VIII was 216 and the base peak was 173 (M\(^+\) : -43), implying fission of a propyl group.

![Diagram](image)

**Fig. 3.** Nuclear Overhauser Effect (%) of Compound (VI) in CD\(_3\)COCD\(_3\)

**H\(_1\) - H\(_3\): proton irradiated**

**H\(_2\): proton observed NOE**

The molecular weight of compound (IV), the fifth peak on the gas chromatogram in Fig. 1b, was determined as 214 by GC-MS. Ehrlich reaction was positive. The UV spectrum absorbed at 196, 231, 290, and 312 m\( \mu \) suggesting a conjugated furanodiene moiety. The NMR spectrum (60 Mc) showed three methyl proton signals, one a secondary methyl at 9.18 \( \tau \) and
the other on a double bond at 8.13 and 8.23 $\tau$; also two vinyl protons at 3.94 $\tau$ (doublet, $J = 2.6$ cps) and 4.39 $\tau$ (multiplet). From above data, two structures regarding the position of the double bond can be assigned. Final assignment was accomplished by NOE technique in NMR. The results are summarized in Fig. 4.

When the vinyl proton observed at 3.94 $\tau$ was irradiated at the C$_3$ methyl proton frequency, it showed 21% enhancement by NOE. Accordingly, this proton must be located at C$_4'$ not at C$_9$. Likewise, irradiation at the frequency of the methyl proton at 8.23 $\tau$ gave a 25% increase of H$_4$ by NOE; H$_4'$ therefore, should lie between the methyl on the furan ring and the methyl on the double bond. From the above observation we established the structure of compound (IV) as 3,5,8-trimethyl-7,7a,8,9-tetrahydroazuleno[6,5-b]furan. It is interesting that the hydroazulene (IV) is an optical active compound ($[\alpha]_D^{20} = -164^\circ$), besides having a negative circular dichroism band at 304 m$\mu$ ($[\theta] = -15000$), indicating that C$_7a$ is the optically active centre.

Configuration of C$_7a$ of the hydroazulene (IV) was intended to determined by comparison of the CD bands at the longest wave lengths of IV, XII, and XIII.

The enol acetate (XII) was prepared from cholesta-4,6-dien-3-one. The furano-diene (XIII) was made from the same starting material according to the known method. The 2,4,6-trieno-compound (XII) showed a positive CD band at 302 m$\mu$ ($[\theta] 11000$); on the other hand, the furanodien-steroid (XIII) exhibited a negative CD band at 286 m$\mu$ ($[\theta] -43000$). It has been reported that the 2,4-dieno-steroid (XIV) and a steroid involving a styrene moiety (XV) have the same chirality at the cisoid diene system, but exhibit opposite Cotton effects. If this relationship holds in the case of the extended systems (XII and XVI), compound (XVI) will show a negative CD band at the longest wave length. The relation between the sign of the Cotton effect and chirality in the mono-en-conjugated furano-oesquiterpene (XVII) is

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10) Conformational analyses of above compounds were studied by K. Tori, M. Ohtsuru, I. Horibe, and K. Takeda, *Chem. Commun.*, 1968, 943, showing that zeylanine (XVII) has a left-handed skew diene. Further, zeylanane and XVII were reported to show a positive CD band at 255 m$\mu$([$\theta$] 77500 and 61500(shoulder), respectively. Therefore, it is assumed that the CD band at 255 m$\mu$ is responsible for a mono-en-conjugated furan.
similar to that in the styrene compound (XV). These relations are assumed to be correct also in the case of the furano-dien (XIII and IV). Therefore, the configuration of the hydrogen on C\textsubscript{7a} of IV will be α.

The forth peak (III) in Fig. 1b, was prepared carefully from Ib by the palladium catalyst at 180°, showed high sensitivity to air and temperature, and had a molecular weight of 212 (from GC-MS). The fact that the NMR spectrum exhibited a vinyl proton and an exomethylene group at 3.86 τ (singlet), 4.83 and 5.15 τ respectively is supported by absorption at 863, and 853 cm\(^{-1}\) in the IR spectrum. Maximum absorptions in the UV spectrum at 324 and 240 μλ are reasonably ascribed to a conjugated furanodiene. The compound (III), therefore, is assumed to be derived through elimination of acetic acid from lindeneryl acetate (Ib).

### Table I. Azulene Formation from Various Compounds

<table>
<thead>
<tr>
<th>Starting materials</th>
<th>Azulenes (%)(^a)</th>
<th>Other products (%)(^e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Structure]</td>
<td>50(^b)</td>
<td>5(^g)</td>
</tr>
<tr>
<td>[Structure]</td>
<td>50(^b)</td>
<td>4(^g)</td>
</tr>
<tr>
<td>[Structure]</td>
<td>17(^b)</td>
<td>83(^g)</td>
</tr>
<tr>
<td>[Structure]</td>
<td>&lt;0.3(^b)</td>
<td></td>
</tr>
<tr>
<td>[Structure]</td>
<td>&lt;0.3(^b)</td>
<td></td>
</tr>
<tr>
<td>[Structure]</td>
<td>3(^b)</td>
<td></td>
</tr>
<tr>
<td>[Structure]</td>
<td>&lt;0.1(^b) + &lt;0.1(^e)</td>
<td>4(^f)</td>
</tr>
<tr>
<td>(α′, β′)</td>
<td>0(^f)</td>
<td></td>
</tr>
<tr>
<td>(α′, β′)</td>
<td>0(^f)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Reaction was carried out by a catalyst combined GC.
\(^b\) Peak area as a percentage of the total peak area eluted up to azulene.
\(^c\) linderazulene
\(^d\) compound (IV)
\(^e\) starting material
\(^f\) methoxy linderazulene
\(^g\) guaiiazulene

Each fraction obtained from the preparative GC, and other various related compounds, were submitted to dehydrogenation combined with gas chromatograph as above. The yields of azulenes are listed in Table I. The compound (IV) was converted to linderazulene(II), in 17% yield with the rest recovered, proving it to be an intermediate. The other fractions were recovered without further conversion to the azulene (II). Compound (III) gave the same products, azulene (II) and the intermediate (IV), and in the same yields as the acetate (Ib) did. Thus, the main reaction path, in the dehydrogenation of Ib by palladium, proceeds to the compound (III) by the elimination of acetic acid, followed by direct dehydrogenation to linder-
azulene (II), while some of III is dehydrogenated to the final product (II) via reduction to the hydroazulene (IV).

The results in Table I show that high yields of azulene are given by compounds in which the elimination of the C4 acetoxy group produces a highly conjugated dihydrobenzofuran system. Therefore, further conjugation with dihydrobenzofuran will accelerate the change to a more stabilized system. This is the case with Ib and III.

The hydroazulene (IV) and lindenene (V) are reduction products of the starting material (Ib), not the products of dehydrogenation. Experiments were performed to find out what function is played by the palladium catalyst. Changes in the yields of the products given on repeated dehydrogenations of lindeneny acetate (Ib) are shown in Fig. 5.

At the earlier stage of this reaction series the yield of linderazulene (II) was extremely high, but with subsequent reactions the yield of II decreased with a simultaneous increase of lindenene (V) and the hydroazulene (IV), the yields of which finally reached a plateau. This result supports the direct conversion of the intermediate (III) into II as the main dehydrogenation route, as mentioned above,

![Chart 1](image)

**Fig. 5. Relationship of the Career of Palladium Catalyst and Products**

- Yields are peak area as a percentage of the total area of the peaks eluted up to linderazulene.
- In one reaction, Ib (6 mg) was submitted to a non-priming catalyst at 300°, N2; 10 ml/min.
since both IV and V are secondary products produced by hydrogenation over palladium hydride or hydrogen chemisorbed.\textsuperscript{11)}

\begin{align*}
\text{Chart 2}
\end{align*}

\textsuperscript{11)} Ten milligram of Ib was subject with the Pd catalyst which had passed hydrogen at 300°, at a rate of 10 ml/min for 10', according to the general method.

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>II</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated with $H_2$</td>
<td>27.4</td>
<td>11.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Non-treated with $H_2$</td>
<td>33.2</td>
<td>6.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Yields of lindenene (V) are the same for both catalyst treated and non-treated with hydrogen, but the yield of the hydroazulene (IV) obtained by the hydrogen-treated catalyst was 1.8 times as large as that by the non-treated catalyst. This experiment will suggest that hydrogen may hydrogenate the intermediate.

In considering the mechanism of dehydrogenation by palladium, the most important result is that the intermediate (IV) has optical activity at \( C_7 \). Therefore, this reaction should proceed by a concerted mechanism. As shown in Chart 2, the following four routes may be possible.

In route a, the ten-membered ring intermediate is optically inactive and would result in an optically inactive hydroazulene (IV).

Following route b, the bourbonene type intermediate would be very slow to rearrange to the azulene, since \( \alpha \) - and \( \beta \) - bourbonene were found to be unaffected under the dehydrogenation conditions used, as seen in Table I.

By route c, reduction with hydrogen would proceed simultaneously with the electrocyclic process. Therefore, if followed, this route would not result in preferential production of azulene to the intermediate (IV). These three routes are therefore inconsistent with the results obtained.

By route d, the first step calls for a \([1, 7]\) hydrogen shift, which is “forbidden” by the Woodward–Hoffmann rules.\(^{13}\) But several examples have recently been reported where a system which is symmetry “forbidden” becomes “allowed” when the reaction is catalyzed by various transition metal complexes.\(^{14} \)

Then, the supposed intermediate (IX) is dehydrogenated \( \text{via} \) an electrocyclic process analogous to the thermolysis of thuene.\(^{15} \)

It is interesting that the dehydrogenation of Ib by palladium proceeds with retention of optical activity, compared with the thermolysis of thuene in which the optical activity is lost. It is difficult to explain reasonably the reduction of the supposed intermediate (IX) to the hydroazulene (IV) according to the above electrocyclic process; as a more complex process would be involved. Valence tautomerization catalyzed by some transition metals have frequently been explained in terms of concerted electrocyclic processes.\(^{14-16} \)

But the isomerization reaction of \( \text{exo-} \) tricyclo [3.2.1.0\(^{2,5}\)] octene with a rhodium catalyst\(^{17} \) was explained by the participation of a carbon-metal insertion reaction. To prove the presence of a route \( \text{via} \) the \( \sigma \)-bonded metal intermediate (XI), the following experiment was tried.

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**Table:**

<table>
<thead>
<tr>
<th>Dehydrogenation Condition</th>
<th>Priming</th>
<th>Starting Solvent</th>
<th>Temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Material</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>A</td>
<td>C</td>
<td>350</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>A</td>
<td>C</td>
<td>300</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>B</td>
<td>C</td>
<td>300</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>B</td>
<td>D</td>
<td>300</td>
</tr>
</tbody>
</table>

**Fig. 6.** Dehydrogenation of Ib and Its Deuterate in Perdeuteriopentane

- **A:** lindenyl trideuteriacetate
- **B:** lindenyl acetate (Ib)
- **C:** perdeuteriopentane
- **D:** pentane

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Lindeneryl acetate (Ib) and lindeneryl trideuterioacetate dissolved in pentane or perdeuteriopentane were dehydrogenated by the palladium catalyst, and the products examined by GC-MS. The intensities of the molecular ion peaks of hydrolinderazulene (IV) and the azulene (II) are shown in Fig. 6. The result that the dehydrogenation of the acetate dissolved in deuteriopentane by the palladium catalyst primed by cholesterol gave products without incorporation of deuterium indicates that the catalyst did not abstract deuterium from the solvent. When the trideuterioacetate dissolved in deuteriopentane was submitted to the primed catalyst, not only the hydroazulene (IV) but the azulene (II) contained deuterium, and high incorporation of deuterium was observed for the nonprimed catalyst at 350°. The high order of incorporation may result from a temperature high enough for the abstraction of deuterium from the solvent. Accordingly, the abstraction of hydrogen from pentane may be possible at 300° by taking account of deuterium isotope effect. It is supposed from these results that the dehydrogenation by palladium at 300° presumably causes not only abstraction of hydrogen from both reactant and solvent but also the donation of hydrogen to the reactant and intermediate simultaneously, leading to the dehydrogenated or hydrogenated products with a scrambling of hydrogen. It should be emphasized that the above results indicate that the dehydrogenation proceeds neither by a single concerted electrolytic process nor by a single hydrogenation by metal hydride or chemisorbed hydrogen; also the function of the acetate is not clear.

Experimental

Melting point were measured on a Kofler block (Yanagimoto & Co.). CD spectra was measured in CH₂Cl₂ with a Jasco model ORD/UV-5 optical rotatory dispersion recorders. NMR spectra were taken in CDCl₃ using tetramethylsilane as an internal standard with a Varian A-60 spectrophotometer, unless otherwise stated. Proton spin-decoupling experiments at 100 Mc were made by using a Varian HA-100 spectrometer and a Hewlett-Packard HP 200 ABR audio-oscillator in the TMS locked mode and frequency sweep operation. Gas chromatography was carried out for analytical use; by a Shimadzu GC-4ATF equipped with a flame ionization detector, column: 1% carbowax 20 M and 1% Apiezon L respectively on Gas Chrom Q (100/120 mesh) 1.5m x 4 mm (glass column); for preparative use: by a Varian Aerograph model 1240-B, SE-30, carbowax 20 M, QF-1 respectively 5% coated on Chromosorb W (30/60 mesh, acid-washed, dimethyldichlorosilane treated) 10' x 3/8' (glass column). Kovats indices were obtained under column temperature 170°. GC-MS was performed by a Hitachi model K-53 (1% Apiezon L or 1% carbowax 20 M on Gas Chrom Q (100/120 mesh), 2 m x 3 mm SS column)-Hitachi model RMU-6E mass spectrometer equipped with a Biemann type separator as a interface, or a Varian Aerograph model 1200 (1% carbowax 20 M on Gas Chrom Q (100/120 mesh), 6' x 1/8' SS column)-Varian Matt M-66 mass spectrometer using a Llewellyn type separator. Conditions for GC-MS are as follows: injection temp. 180°, column temp. 160°, He 1.0 kg/cm² (35 ml/min), connecting tube 180°, molecular separator 180°, ion-chamber 70 eV.

Priming of Palladium on BaCO₃ by Cholesterol (for Preparative Use)—Five percent palladium on BaCO₃ (24/32 mesh) was packed into a preparative column (10 cm x 9 mm) 30 mm in length. The one end of the column have a carrier gas inlet and a sample injector sealed with a silicon rubber septum, and the other end was connected to a glass tube with glass joint, which was fastened by spring. The catalyst column was heated at 300° in a furnace and carrier gas (N₂) was passed at a rate of 10 ml/min. Twenty μl of 3% solution of cholesterol dissolved in CH₂Cl₂ was injected 10 times every half a minutes; then temperature of the column was held at 350° for 1 hr.

Palladium Dehydrogenation Reaction combined with Gas Chromatography—The catalyst of 5% palladium on BaCO₃ (24/32 mesh) primed by cholesterol was packed at 25 mm length in a column (50 mm x 4 mm φ), the catalyst column was inserted into a injection block, and connected to a GC column by a SS pipe with a silicone rubber stopper.

For azulene formation; column: 1% Apiezon L 2.0 m x 4 mm, injection 370°, column 205°, detector 250°, N₂ 12 ml/min. A pentane solution (1—10 μg sample) was injected.

For checking intermediates, 1% carbowax 20 M 2.0 m x 4 mm, injection 170—370°, column 180°, N₂ 12—50 ml/min.

General Method of Dehydrogenation by Palladium Catalyst—The catalyst column used was same as the one mentioned at the priming method of the catalyst. Each 20 μl of 1% solution of sample dissolved in pentane was injected in the catalyst column at any temperature and carrier gas velocity for every half a

minute. The product was trapped at the outlet of the column with dry ice-acetone cooling. The product was transferred as a pentane solution.

**Dehydrogenation of Lindenylen Acetate (Ib)**—The catalyst column: 200–250°C, N₂: 10 ml/min. The product (0.88 g) obtained from Ib (2.2 g) was chromatographed on Al₂O₃ (activity III). The fraction eluted before linderazulene (II) (purple) was fractionated by a preparative GC. The column used was as follows:

![Diagram of fractionation process]

Fr. 2: The second peak on the gas chromatogram Fig. Ib, was identified as lindenene (V) from comparison of NMR, IR, GC, GC-MS spectra.

Fr. 3 (VI): The third peak on the gas chromatogram in Fig. Ib was a pale blue oil. IR νₑₛₑ cm⁻¹: 1643, 899, 879, 856, 787. UV λₑₓₑmax nm (ε): 212.5 (25200), 272 (2840), 281 (2950), 285 (2900), 291 (2800).

Fr. 4 (IV): The fourth peak on the gas chromatogram in Fig. Ib, mp 96–99°C (from acetone). IR νₑₛₑ cm⁻¹: 1623, 898, 891, 851, 742. UV λₑₓₑmax nm (ε): 195 (8900), 232 (14600), 238 (14000), 290 (10300), 309 (11500), 313 (8200). GC-MS: 214 (M⁺), 199 (M⁺-CH₂). [α]D 164° (c=1.353, CH₂Cl₂). CD ε(6) 315 i (-9800), 304 (-15000), 247 (-4800).

VI from Pyrolysis of Lindenylen Acetate ( Ib)—Lindenylen acetate (975 mg) was pyrolysed according to the general method for dehydrogenation except for the following condition: catalyst: BaCO₃ (24/32 mesh) Coulomb 180°C, N₂ 10 ml/min. The trapped product dissolved in pentane was chromatographed on Al₂O₃ (activity III). The eluate from pentane gave VI 24 mg.

**Catalytic Hydrogenation of VI**—Compound (VI), (10 mg) dissolved in methanol (0.5 ml) was hydrogenated with 5% Pd-C (5 mg). After 30', 1 mole eq. hydrogen was absorbed, the solution was filtered, the filtrate was evaporated to leave oil (10 mg). GC: 1H-νmax 2025, 1H-νmax 1576. GC-MS 214 (M⁺). NMR ν: 9.07 (3H, J=7 cps), 7.72 (3H, singlet), 4.55 (1H, triplet), 2.83 (1H, multiplet), 2.23 (1H, multiplet).

**Catalytic Hydrogenation of VII**—Compound (VII) (10 mg) dissolved in EtOH (0.5 ml) was hydrogenated with Rh-Pt catalyst 19 (15 mg). After 2 hr, the catalyst was filtered the resulting filtrate was evaporated to give an oil. GC: a new peak (VIII) (accompanying with VII) 1H-νmax 2100, 1H-νmax 1641. GC-MS: 216 (M⁺) 173 (M⁺-CH₂).

**Preparation of III**—Lindenylen acetate (Ib), (150 mg) was treated according to the general methods of dehydrogenation: catalyst: 50% Pd on Chromosorb W (30/60 mesh), 180°C, N₂ 30 ml/min. The product was trapped as a pentane solution, chromatographed on Al₂O₃ (activity III). III was obtained as an oil (9 mg). IR νₑₛₑ cm⁻¹: 1629, 863, 853. UV λₑₓₑmax nm (ε): 202 (7800), 222 (8000), 240 (10000), 324 (5800). GC-MS: 212 (M⁺), 197 (M⁺-CH₂). NMR ν: 8.97 (3H, singlet), 8.03 (3H, d, J=1 cps), 5.13 (1H, multiplet), 4.83 (1H, multiplet), 3.86 (1H, singlet), 3.10 (1H, triplet).

2-Formyl-cholesta-4,6-dien-3-one—Cholesta-4,6-dien-3-one (1 g) was dissolved in benzene (20 ml), ethyl formate (1 ml), NaH (50% o.6 g) was added with stirring under N₂ atmosphere. After 3 hr, methanol was added to decompose NaH, further H₂O added, and the precipitate was collected, washed with ether. The aqueous layer combined with the precipitate was acidified with 2N HCl, extracted with ether-CH₂Cl₂. The organic layer was washed with H₂O, dried over Na₂SO₄, and evaporated. 975 mg, mp 117–118°C, yellow prisms (from hexane). Found: C, 82.06; H, 10.23. Calcd. for C₂₃H₄₆O₂: C, 81.89, H, 10.31.

2-Formyl-3-methoxy-cholesta-2,4,6-triene—A solution of 2-formyl-cholesta-4,6-dien-3-one (470 mg) was dissolved in methanol (20 ml), added p-toluene sulfonic acid (1 mg), and refluxed 10 min. After cooling, one drop of pyridine was added, followed addition of water, the mixture was extracted with CH₂Cl₂-MeOH. The extract was washed with H₂O, dried over Na₂SO₄. 398 mg, mp 120.5–122°C, needles from pentane. Found: C, 82.13; H, 10.52. Calcd. for C₂₅H₄₄O₂: C, 82.09; H, 10.44. UV λₑₓₑmax nm (ε): 256 (21000), 328 (shoulder) (7160). NMR (CDCl₃) ν: 8.17 (3H, singlet), 4.30 (1H, singlet), 3.91 (2H, singlet), 2.85 (doublet—multiplet, J=2 cps).

5-Ethoxycarbonylifuran[3', 4'-2, 3]cholesta-4, 6-diene—To a solution of above 3-methoxy compound (2.0 g) dissolved in diglyme (30 ml) at 170°C with stirring, CuSO₄ (one bit) was added, followed addition of

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a solution of ethyl diazoacetate (2.1 g) dissolved in diglyme (20 ml) in a period of 30’, further stirring and heating was continued for 1.5 hr. After cooling, the mixture was extracted with ether, and the extract was evaporated to dryness. Recrystallization from pentane gave 1.2 g, mp 132—134°. Found: C, 80.64; H, 9.69. Calcd. for C₉₂H₄₆O₃: C, 80.27; H, 9.69. [α]D²⁺⁻323.6° (0.5322%, CH₂Cl₂). NMR r: 5.70 (2H, quartet, J=7 cps), 4.25 (1H, doublet—multiplet, J=10 cps), 3.85 (1H, doublet—multiplet, J=10 cps) 3.46 (1H, multiplet), 2.85 (1H, multiplet).

Furano[3′,4′-2,3]cholesta-4,6-diene (XV)—To a solution of above ester (300 mg) dissolved in benzene (2 ml), 2% KOH—EtOH solution (30 ml) was added, refluxed 30’ min. After cooling, the precipitate was collected, washed with EtOH, extracted with 10% AcOH—CH₂Cl₂. The extract was washed with water, dried over Na₂SO₄, evaporated to leave a residue 235 mg. The residue was mixed with copper powder, heated at 240—260° for 5’ min. After cooling the product was dissolved in pentane, chromatographed on Al₂O₃. Fraction eluted with pentane (156 mg) was recrystallized from ether—MeOH mp 80—82°. Found: C, 85.71; H, 10.40. Calcd. for C₃₂H₄₈O: C, 85.65; H, 10.41. [α]D²⁺⁻149°. CD: mμ [θ] 280 (-43000). UV λmax, cm⁻¹ mμ (ε): 281 (28900). NMR r: 4.40 (1H, doublet—multiplet, J=10 cps), 3.99 (1H, doublet—multiplet, J=10 cps), 3.89 (1H, singlet), 2.92 (1H, multiplet), 2.82 (1H, doublet, J=1.5 cps).

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