Studies in the Steroid Group. Part LXVIII. Epidioxides derived from Lumisterol and Related Compounds.*

By Peter Bladon.

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The photochemical reaction of lumisteryl acetate with oxygen yields dehydrolumisteryl acetate, lumisteryl acetate β-epidioxide, dehydrolumisteryl acetate α- and β-epidioxides, and 3β-acetoxylumista-5 : 8(9) : 22-trien-7-one. The structure of the β-epidioxides follows from their rearrangement in alkaline solution to 8β-hydroxylumista-4 : 6-dien-3-ones.† The mechanism of this reaction is discussed. The 7-ketone is readily transformed into a phenol by the dienone–phenol rearrangement.

In several papers (Bladon, Clayton, Greenhalgh, Henbest, Jones, Lovell, Silverstone, Wood, and Woods, *J.*, 1952, 4883; Henbest, Jones, Wood, and Woods, *J.*, 1952, 4894; Clayton, Crawshaw, Henbest, Jones, Lovell, and Wood, *J.*, 1953, 2009; Clayton, Henbest, and Jones, *J.*, 1953, 2015; Bladon, Henbest, Jones, Lovell, and Woods, *J.*, 1954, 125), the use of dehydroergosterol and ergosterol epidioxides as intermediates in the synthesis of cortical hormones was described. As an extension to that work, this paper describes the analogous epidioxides from lumisterol (I; R = H) (the isomer of ergosterol having the $C_{(19)}$-methyl group in the α-configuration). The work also forms part of investigations of steroids having abnormal configurations at one or more of the angular positions, being carried out in these laboratories.

* Part LXVII, *J.*, 1954, 800.

† Compounds described in this paper having a 10α-methyl group are named as derivatives of lumistane. The configuration of atoms or groups at the asymmetric carbon atoms $C_{(5)}$ and $C_{(8)}$ is indicated in the name when it is known, but unless otherwise stated the hydrogen atom at $C_{(9)}$ has the α-configuration.

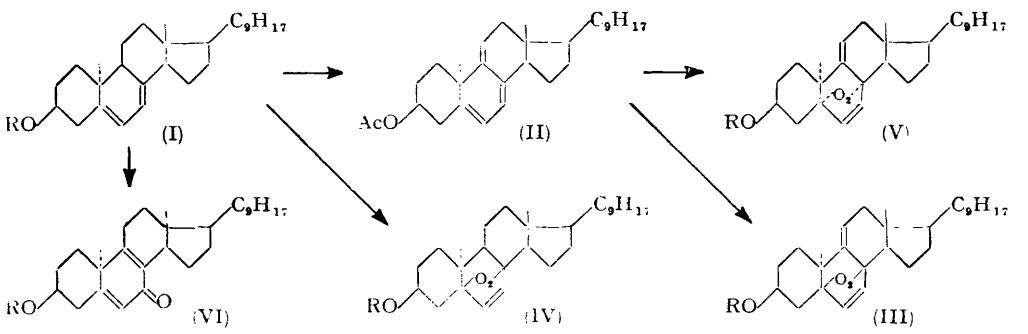
There is no literature record of the preparation of an epidioxide (peroxide) from lumisterol.* Accordingly the method used for preparing dehydroergosterol epidioxide (Bladon, Clayton, *et al.*, *loc. cit.*) and ergosterol peroxide (Clayton, Henbest, and Jones, *loc. cit.*) was used initially with lumisteryl acetate (I; R = Ac) as starting material. To avoid hydrolysis alkali was not added to the reaction mixture, but to minimise the effects of acid, which is thought to arise from oxidative splitting of the side-chain double bond, a small amount of pyridine was added.

Under these conditions oxygen was taken up readily at the temperature of refluxing ethanol, the reaction being complete in 16 hr. Although a fairly pure solid could be isolated by direct crystallisation, discrepancies in the optical rotation of samples pointed to its being impure, and by chromatography on alumina four pure substances were isolated.

The products in ease of elution were: (i) The known 9(11)-dehydrolumisteryl acetate (II). (ii) The epidioxides. Separation of these compounds was not clear-cut, and was followed by change in rotation. The two compounds isolated were (in order of elution): 3β-acetoxy-5β : 8β-epidioxylumista-6 : 9(11) : 22-triene (dehydrolumisteryl acetate β-epidioxide) (III; R = Ac) (obtained also directly from dehydrolumisteryl acetate, see below), and 3β-acetoxy-5β : 8β-epidioxylumista-6 : 22-diene (lumisteryl acetate β-epidioxide) (IV; R = Ac). Several other fractions were mixtures of these compounds and probably dehydrolumisteryl acetate α-epidioxide (V; R = Ac). The assignment of the configurations of the epidioxides is discussed later. (iii) 3β-Acetoxylumista-5 : 8(9) : 22-trien-7-one (VI; R = Ac), the structure being assigned on the following evidence.

The infrared spectrum showed the presence of an unsaturated ketone function, an acetyl group, and the Δ^{22} side-chain double bond. Analyses of the compound and of the corresponding hydroxy-derivative favour $C_{30}H_{44}O_3$ and $C_{28}H_{42}O_2$ respectively, indicating the presence of two double bands in the nucleus.

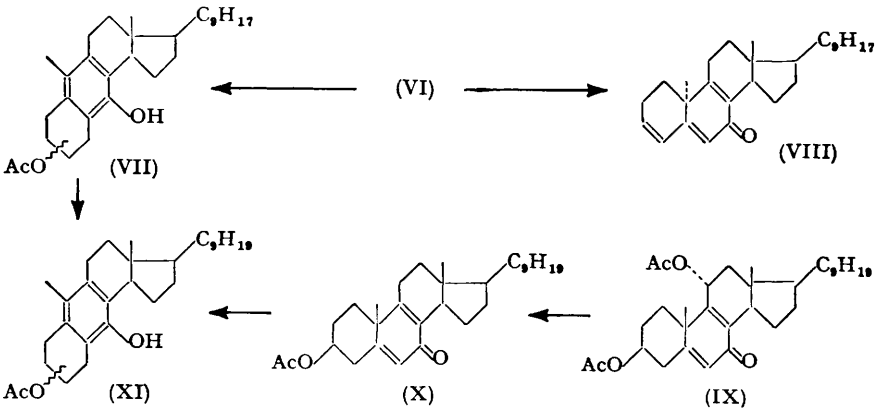
The ultraviolet spectrum ($\lambda_{max.}$ 246 mμ; ε 11,800) precludes an αβ–γδ unsaturated ketone system and suggests the cross-conjugated $\Delta^{5:8(9)}$-7-ketone. The ergosterol analogue of (VI) (Elks, Evans, Long, and Thomas, *J.*, 1954, 451; Elks, Evans, Oughton, and Thomas, *ibid.*, p. 463) has $\lambda_{max.}$ 245 mμ (ε 11,800). The other cross-conjugated system, a $\Delta^{4:7}$-6-ketone, is also a possibility, although the absorption would be expected to show a maximum



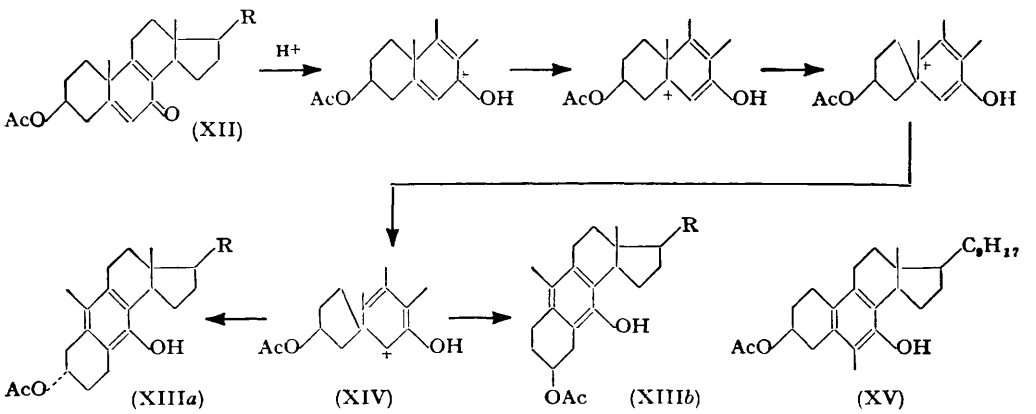
($\lambda_{max.}$ 240—241 mμ) intermediate between those associated with the separate chromophores [Δ^4-3β-acetoxy-6-ketone ($\lambda_{max.}$ 236 mμ; ε 6300) (Heilbron, Jones, and Spring, *J.*, 1937, 801; Jackson and Jones, *J.*, 1940, 659) and Δ^7-6-ketone ($\lambda_{max.}$ 245 mμ; ε 14,000) (Barton and Robinson, *J.*, 1954, 3045)] in accordance with the principles stated by Elks, Evans, Long, and Thomas (*loc. cit.*). This alternative is excluded by failure of treatment with activated zinc and acetic acid to cause elimination of the acetoxy-group, a reaction characteristic of γ-acetoxy- and γ-hydroxy-αβ-unsaturated ketones (Amendolla, Rosenkranz, and Sondheimer, *J.*, 1954, 1226; Fieser, *J. Amer. Chem. Soc.*, 1953, **75**, 4377; Barton and Laws, *J.*, 1954, 52). Instead these reagents caused rearrangement to a phenol (VII),

* Fieser and Fieser, "Natural Products related to Phenanthrene," Reinhold Publishing Corporation, New York, 3rd Edn., 1949, p. 173, and Shoppee, in Rodd, "Chemistry of Carbon Compounds," Elsevier Publishing Company, Amsterdam, 1954, Vol. II*B*, p. 851, mention "a peroxide of lumisterol"; these are, however, misprints for "an epoxide."

which proves the presence of the $\Delta^{5:8(9)}$-7-ketone system. The dienone–phenol rearrangement is well known among $\Delta^{1:4}$-3-ketosteroids (Inhoffen and Stoeck, *Annalen*, 1949, **563**, 127; Inhoffen and Becker, *Chem. Ber.*, 1953, **86**, 116; Wilds and Djerassi, *J. Amer. Chem. Soc.*, 1946, **68**, 1712, 2125; Djerassi and Scholz, *ibid.*, 1947, **69**, 2404; 1948, **70**, 1911; *J. Org. Chem.*, 1948, **13**, 697; Djerassi, *ibid.*, p. 848), but hitherto only two examples have



involved ring B dienones. Barton and Thomas (*J.*, 1953, 1842) describe the rearrangement of 7-oxolanosta-5 : 8-dien-3β-yl acetate with zinc and acetic acid (silver nitrate not added), but do not assign a structure to the phenol formed ($\lambda_{max.}$ 287 mμ; ε 3500 in neutral solution and $\lambda_{max.}$ 302 mμ; ε 3500 in alkaline solution), and Kyosuke Tsuda, Ko Arima, and Ryoichi Hayatsu (*J. Amer. Chem. Soc.*, 1954, **76**, 2933) describe the rearrangement of 7-oxocholesta-5 : 8-dien-3β-yl acetate (XII; R = C_8H_{17}) with sulphuric acid in acetic anhydride, and the subsequent dehydrogenation of the phenol to a mixture of anthracene derivatives. On the basis of this evidence they assign the phenol the structure (XIII*a*; R = C_8H_{17}) with the acetoxy-group in position 3 *. However, the 2-acetoxy-structure (XIII*b*; R = C_8H_{17}) is equally possible if the mechanism takes the following course:



It is impossible on the available evidence to decide in which direction the asymmetrical *spiro*-intermediate (XIV) will rearrange.

It is not certain that the rearrangement of the lumisterol derivative takes a similar course and yields an octahydroanthracene derivative (VII; OAc group in position 2 or position 3) rather than the alternative course involving migration of the angular methyl group to a 6-methyl-19-*nor*-steroid phenol (XV), because in the present case it has been impossible to effect the rearrangement by the conventional reagents.

It is implicit in this mechanism that the asymmetry at $C_{(10)}$ is lost in the reaction, and

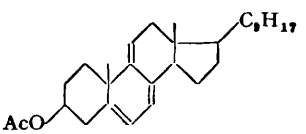
so it should be possible to obtain the same compounds from the lumisterol and the ergosterol series. This has been achieved. Treatment of 3β : 11α-diacetoxyergosta-5 : 8(9)-dien-7-one (IX; *J.*, 1953, 2916), with zinc and acetic acid in the presence of a *small* amount of silver nitrate, resulted in formation of 3β-acetoxyergosta-5 : 8(9)-dien-7-one (X). With a larger amount of silver nitrate, rearrangement to the phenol (XI) occurred. This same phenol was obtained on hydrogenating the side-chain double bond in the phenol (VII) obtained in the lumisterol series.*

Mild hydrolysis of the acetoxylumistatrienone (VI; R = Ac) yields the corresponding 3-hydroxy-compound (VI; R = H). However, under more vigorous conditions as would be expected for a αβ-unsaturated δ-hydroxy-ketone [cf. the formation of cholesta-3 : 5-dien-7-one from 7-ketocholesteryl acetate (Mauthner and Suida, *Monatsh.*, 1896, **17**, 579)] dehydration ensues with formation of lumista-3 : 5 : 8(9) : 22-tetraen-7-one (VIII), the light absorption of which ($\lambda_{max.}$ 272—273 mμ; ε 13,800) agrees with that of the corresponding ergosterol analogue ($\lambda_{max.}$ 272 mμ; ε 14,600) (Elks, Evans, Oughton, and Thomas, *loc. cit.*).

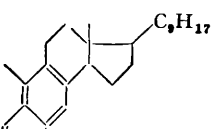
The complexity of the products from the photo-oxygenation prompted study of the reaction at lower temperatures. The temperature of refluxing ethanol was used in preparing ergosterol and dehydroergosterol epidioxides largely on account of the low solubilities in cold alcohol. However successful preparations were carried out in the cold (private communication from Dr. R. M. Evans of Glaxo Laboratories, Greenford, Middlesex). Because of the greater solubility of lumisterol derivatives, the high temperature was not essential. An apparatus similar to that described by Barton and Laws (*J.*, 1954, 52) was used, with eosin as sensitising dye. Lumisteryl acetate then gave three products: dehydrolumisteryl acetate (II), lumisteryl acetate β-epidioxide (IV; R = Ac), and 3β-acetoxylumista-5 : 8(9) : 22-trien-7-one (VI). Careful chromatography of the products failed to reveal the presence of any other epidioxide.

Dehydrolumisteryl acetate gave under both high- and low-temperature conditions, the same mixture of two epidioxides, the most easily eluted from the chromatogram column being identical with the material (III; R = Ac) isolated in the high-temperature photo-oxygenation of lumisteryl acetate. The second compound is the isomeric 3β-acetoxy-5α : 8α-epidioxylumista-6 : 9(11) : 22-triene (dehydrolumisteryl acetate α-epidioxide) (V; R = Ac). At low temperature the yield of mixed epidioxides was 83%, and the unsaturated ketone (VI) was not isolated in either experiment.

* Nes and Mosettig (*J. Amer. Chem. Soc.*, 1953, **75**, 2787; 1954, **76**, 3182, 3186) have described the formation of a hydroanthracene hydrocarbon derivative by treatment of dehydroergosteryl acetate (XVI) with a small amount of hydrogen chloride in chloroform. One (XVII) of the suggested structures has the same carbon skeleton as (XIII), and indeed it is possible to formulate a mechanism for this "anthrasteroid" rearrangement which is very similar to that of the dienone–phenol rearrangement.

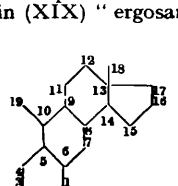


(XVI)

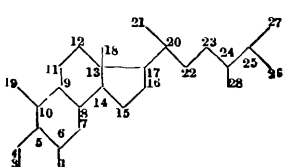


(XVII)

These authors term the parent saturated ring system (XVIII) "anthrastane" and the system with an ergostane side chain (XIX) "ergosanthrastane."



(XVIII)



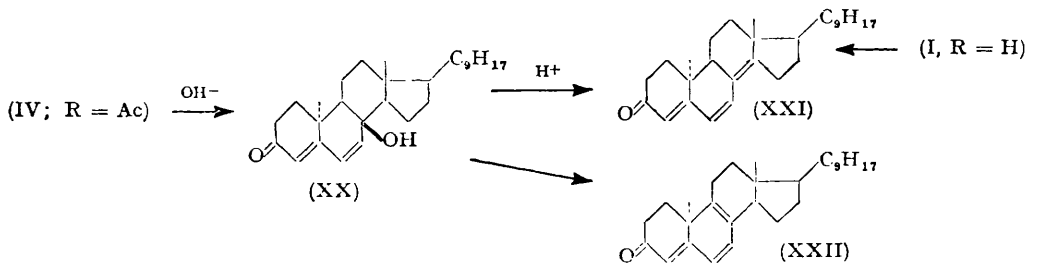
(XIX)

The numbering system used follows the suggestion of Inhoffen and Brückner (*Fortschr. Chem. org. Naturstoffe*, 1954, **11**, 83). Thus the product of the dienone–phenol arrangement of the lumisterol derivative is 3α- (or 2β-)-acetoxyanthraergosta-5 : 7 : 9 : 22-tetraen-7-ol.

Failure to isolate lumisteryl acetate α-epidioxide from the photochemical oxidation of lumisteryl acetate, while two epidioxides are obtained from dehydrolumisteryl acetate, suggests that this α-epidioxide is unstable. Furthermore, since in the cold, lumisteryl acetate does not give the dehydrolumisteryl acetate epidioxides, but only when hot, it may be supposed that initially lumisteryl acetate α-epidioxide is formed (together with the β-epidioxide), and at high temperature, or in working up, this breaks down to dehydrolumisteryl acetate and possibly the ketone (VI).

Ergosterol and dehydroergosterol epidioxides are stable in alkaline solution (Clayton, Henbest, and Jones, *loc. cit.*), as expected with compounds in which the epidioxide bridge joins two tertiary carbon atoms. It was somewhat surprising, therefore, that hydrolysis of lumisteryl acetate β-epidioxide yielded not the 3-hydroxy-compound but a compound $C_{28}H_{42}O_2$. The infrared spectrum shows the presence of a hydroxyl group (which is not acetylated by acetic anhydride and pyridine at room temperature, and is therefore most likely tertiary) and an unsaturated ketone group, and the absence of an acetyl group. The ultraviolet spectrum ($\lambda_{max.}$ 282—285 mμ; ε 26,000) corresponds to either a $\Delta^{3:5}$-7-ketone [Greenhalgh, Henbest, and Jones, *J.*, 1952, 2375; Jackson and Jones, *J.*, 1940, 659 ($\lambda_{max.}$ 277—280 mμ; ε 24,000—28,000)] or a $\Delta^{4:6}$-3-ketone [Wilds and Djerassi, *J. Amer. Chem. Soc.*, 1946, **68**, 1712; Prelog, Ruzicka, and Stein, *Helv. Chim. Acta*, 1943, **26**, 2237; Antonucci, Bernstein, Giancola, and Sax, *J. Org. Chem.*, 1951, **16**, 1453 ($\lambda_{max.}$ 284 mμ; ε 28,000)]. The second alternative is favoured because the large negative rotation ($[\alpha]_D$ −377°) corresponds to that of cholesta-3 : 5-dien-7-one ($[\alpha]_D$ −300°; Greenhalgh, Henbest, and Jones, *loc. cit.*) rather than that of the isomeric cholesta-4 : 6-dien-3-one ($[\alpha]_D$ +32°; *idem, ibid.*). The α-configuration of the $C_{(10)}$ methyl group in lumista-4 : 6-dien-3-one and lumista-3 : 5-dien-7-one places these compounds in the same stereochemical groups as cholesta-3 : 5-dien-7-one and cholesta-4 : 6-dien-3-one, respectively (cf. Stokes and Bergmann, *J. Org. Chem.*, 1952, **17**, 1194). The alkaline hydrolysis product is therefore assigned the structure 8β-hydroxylumista-4 : 6 : 22-trien-3-one (XX).

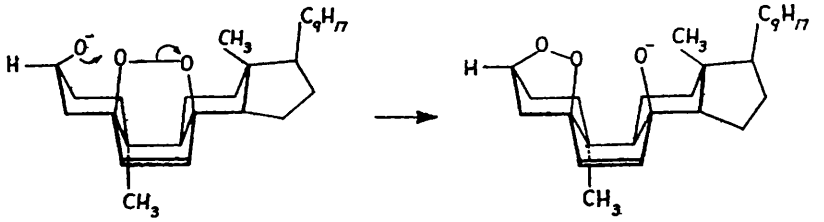
This is proved (particularly with respect to the position of the hydroxyl group and the retention of the normal lumisterol skeleton) by the *trans*-elimination of water in the presence of mineral acid to yield the lumista-4 : 6 : 8(14) : 22-tetraen-3-one (XXI) ($\lambda_{max.}$ 285; ε 8000 and 350—358 mμ; ε 25,000) which was also obtained directly by treatment of lumisterol (I; R = H) with *p*-benzoquinone and aluminium *tert.*-butoxide (cf. Wettstein, *Helv. Chim. Acta*, 1940, **23**, 388; Swiss P. 236,309; Dauben, Eastham, Micheli, Takemura, Mandell, and Chemerda, *J. Amer. Chem. Soc.*, 1953, **75**, 3255). Elks (*J.*, 1954, 468) records $\lambda_{max.}$ 237 (ε 4700), 282 (ε 7100), and 350 mμ (ε 27,100) for the corresponding ergosterol compound similarly prepared. The other direction of *trans*-dehydration to yield lumista-4 : 6 : 8(9) : 22-tetraen-3-one (XXII) ($\lambda_{max.}$ 244; ε 17,900 and 393 mμ; ε 11,000) occurred with refluxing acetic anhydride and pyridine. Elks (*loc. cit.*) records $\lambda_{max.}$ 244·5 (ε 16,700) and 390 mμ (ε 9300) for the analogous ergosterol compound.



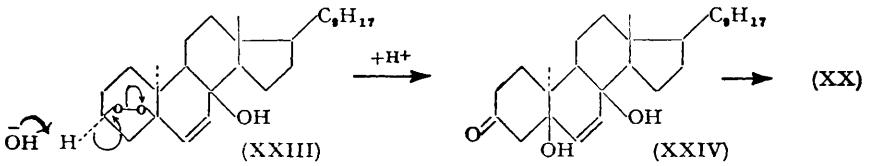
The instability of a ditertiary epidioxide system in alkaline solution has not hitherto been reported, and any proposed mechanism must explain the difference between the behaviour of the ergosterol and lumisterol compounds. The following explanation is tentatively advanced.

Molecular models of lumisterol α- and β-epidioxides reveal that only in the β-isomer are the two oxygen atoms ($C_{(3)}$–OH and $C_{(5)}$–O) close together, both being axial with respect

to ring A (ring B must of necessity be in a boat form). If it is supposed that the first step is the formation of an anion at $C_{(3)}$, then rearrangement can readily occur to give a hypothetical intermediate having a hydroxyl at $C_{(8)}$ and a $C_{(3)}$–$C_{(5)}$ epidioxide bridge (XXIII) *. (The three oxygen atoms $C_{(3)}$–OH, $C_{(5)}$–O, and $C_{(8)}$–O are nearly collinear.) By analogy

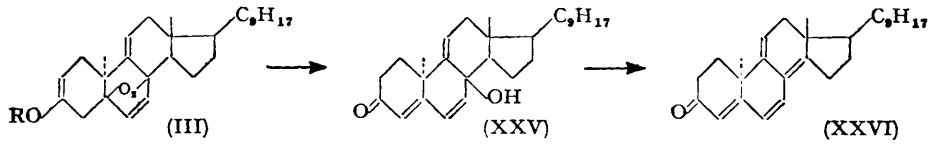


with other secondary–tertiary epidioxides (Skau and Bergmann, *J. Org. Chem.*, 1938, **3**, 166; Conca and Bergmann, *J. Org. Chem.*, 1953, **18**, 1104; Bergmann and Mclean, *Chem. Rev.*, 1941, **28**, 367; Laubach, Schreiber, Agnello, Lightfoot, and Brunings, *J. Amer. Chem. Soc.*, 1953, **75**, 1514; cf. Kornblum and de la Mare, *J. Amer. Chem. Soc.*, 1951, **73**, 880) the epidioxide (XXIII) would be expected to be attacked by hydroxyl or alkoxyl anions:



the intermediate 5-hydroxy-3-ketone (XXIV) would be dehydrated by alkali to yield the 8-hydroxy-dien-3-one (XX).

Such a series of reactions would be impossible in the ergosterol series, where the 3β-equatorial hydroxyl group is too far removed from the epidioxide bridge, and also with (the unknown) lumisterol α-epidioxide, where the epidioxide bridge is on the opposite side of the molecule to the hydroxyl group. The correctness of this scheme was shown since, of the two isomeric dehydrolumisteryl acetate epidioxides, only one isomer, which is hence established as (III; R = Ac), underwent rearrangement; the intermediate 8-hydroxy-compound (XXV) was very unstable; with traces of acid it readily gave lumista-4 : 6 : 8(14) : 9(11) : 22-pentaen-3-one (XXVI).

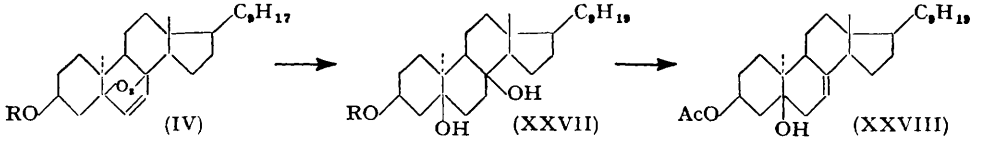


In contrast, the other epidioxide (V; R = Ac) was hydrolysed by alkali to 5α : 8α-epidioxy-3β-hydroxylumista-6 : 9(11) : 22-triene (V; R = H). This compound was however unstable to crystallisation; the nature of the decomposition products was not determined.

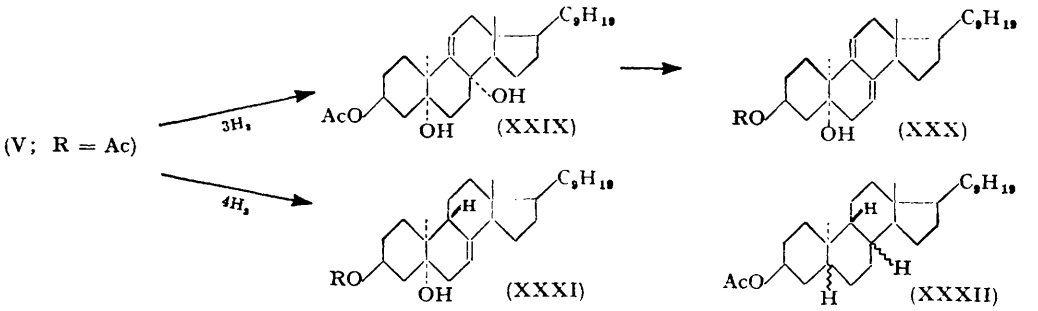
Hydrogenation of lumisteryl acetate β-epidioxide in the presence of Adams's catalyst readily afforded 3β-acetoxylumistane-5β : 8β-diol (XXVII; R = Ac) which differs markedly from the corresponding ergosterol analogue (Clayton, Henbest, and Jones, *loc. cit.*). The infrared spectrum in carbon disulphide shows two sharp hydroxyl peaks (at 3565 and 3435 cm.$^{-1}$) which do not change in relative intensity on change of concentration. This shows that there is little intramolecular and no intermolecular hydrogen bonding between the groups. That the hydroxyl groups are extremely hindered

* This rearrangement is in effect an internal S_Ni reaction with attack on an oxygen instead of a carbon atom.

is shown by the ease of elution of the compound with benzene from alumina. The compound is more stable towards acidic reagents than the ergosterol analogue; it was unchanged by treatment with refluxing acetic acid in acetone whereas under these conditions, the ergosterol compound gives a 5 : 8-epoxide. Phosphoryl chloride in



pyridine, and alcoholic hydrochloric acid were without effect of this compound. However, acetic acid at 100° caused dehydration, to give a poor yield of 3β-acetoxylumist-7-en-5β-ol (XXVIII) (the formulation of this compound is based largely on the doubtful analogy with the ergosterol series).



Similar hydrogenation of dehydrolumisteryl acetate α-epidioxide (V; R = Ac) with 3 mols. of hydrogen gave a syrup, presumably the diol (XXIX), which was readily dehydrated to 3β-acetoxylumista-7 : 9(11)-dien-5α-ol (XXX; R = Ac). With 4 mols. of hydrogen the major product was 3β-acetoxy-9β-(?)-lumist-7-en-5α-ol (XXXI; R = Ac). The structure of this compound is in some doubt however; the 9β-structure is adduced from the known direction of hydrogen addition to dehydrolumisteryl acetate to yield hexahydropyrocalciferol acetate (XXXII) (Dimroth, *Ber.*, 1936, **69**, 1123), in which the hydrogen at C_9 must be β-orientated consequent upon its formation from pyrocalciferol *via* the dihydro-compound (Busse, *Z. physiol. Chem.*, 1933, **214**, 211). On the other hand the double bond may be in the 8 : 9-position. The compounds derived from dehydrolumisteryl acetate α-epidioxide by hydrogenation (XXX and XXXI; R = Ac) have properties in marked contrast to those of the lumisteryl acetate β-epidioxide series; the hydroxy-groups are not hindered and the corresponding diols (XXX; R = H, and XXXI; R = H) are high-melting insoluble compounds; the series generally resembles the ergosterol series.

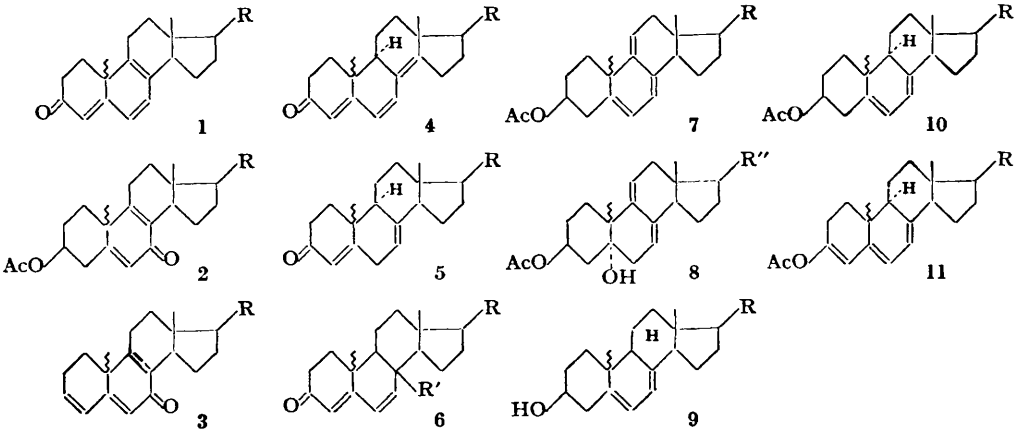
Stereochemical Implications.—Several compounds now described have ergosterol analogues and it is instructive to compare molecular-rotation differences in the pairs in the lumi- and ergo-sterol series differing by inversion of configuration at $C_{(10)}$ (cf. Fieser and Fieser, *op. cit.*, p. 212). Table 1 lists the molecular rotations for such pairs of compounds, together with the difference between them and the average value for the pair.

It is seen at once that there is no constant difference in $[M]_D$ for a change of configuration at $C_{(10)}$. The reason for this is probably that all the compounds listed have powerful chromophores, and the rotations are therefore complicated by optical exaltation (cf. Karrer and Kasse, *Helv. Chim. Acta*, 1919, **2**, 436). On the other hand, these compounds are those with which comparisons are best made, for pairs of saturated derivatives of lumisterol and ergosterol would not give reliable values, because such lumisterol derivatives must frequently necessarily have one of their rings in a boat form.

The average molecular rotations for the pairs of compounds (*A*) represent therotational contribution of all asymmetric centres except $C_{(10)}$. In the pairs Nos. 1, 2, 3, and 7 the other asymmetric centres are at $C_{(13)}$, $C_{(14)}$, $C_{(17)}$, and in the side-chain, and at $C_{(3)}$ (in Nos. 2

and 7). The averages in these cases should be very close to the molecular rotation of the similar *neo*ergosterol derivative in which there is no angular methyl group at $C_{(10)}$ and ring B is aromatic. The last column in the Table records the difference between the average $[M]_D$

TABLE 1.



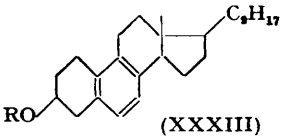
$R = C_8H_{17}$; $R'' = C_9H_{19}$.

	Ketones: Lumisterol series	Ergosterol series	Diff.*	Aver.† (A)	A − $[M]_D^{300}$		Other compounds: Lumisterol series	Ergosterol series	Diff.*	Aver.† (A)	A − $[M]_D^{300}$
1	−3220° [1]	+2940° [2]	+6160°	−142°	−327°	7	+980° [1,3]	+890° [9]	−90°	+835°	+650°
2	−421 [1]	−136 [4]	+285	−279	−237	8	+329 [1]	+292 [10]	−37	+310	—
3	+321 [1]	−680 [4]	−1001	−180	−365	9	+758 [1]	−538 [11]	−1296	+110	—
4	−3000 [1]	+2300 [2,3]	+5300	−350	—	10	+571 [1]	−394 [12]	−965	+88	—
5	+150 [5]	−3 [6,7]	−153	+69	—	11	+1280 [1,6]	−625 [6]	−1905	+328	—
6	−1520 [1] (R′ = OH)	−94 [6] (R′ = H)	+1426	−807	—						

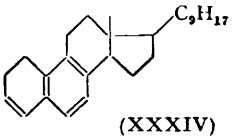
* Diff. = $[M]_D^{\beta} - [M]_D^{\alpha}$. † Aver. (A) = $([M]_D^{\alpha} + [M]_D^{\beta})/2$.

[1] Present work. [2] Elks, *J.*, 1954, 468. [3] Barton and Bruun, *J.*, 1951, 2728. [4] Elks, Evans, Long, and Thomas, *J.*, 1954, 451; Elks, Evans, Oughton, and Thomas, *J.*, 1954, 463. [5] Heilbron, Kennedy, Spring, and Swain (*J.*, 1938, 869) record $[\alpha]_D$ +48·7° for this compound. In our hands the compound prepared from lumisterol either with acetone and aluminium *tert.*-butoxide or *cyclo*hexanone and aluminium *iso*propoxide had a lower rotation {$[\alpha]_D$ +34·5° (*c*, 0·745) and $[\alpha]_D$ +32·3° (*c*, 0·595), respectively}. [6] Heilbron, Kennedy, Spring, and Swain, *loc. cit.* [7] Oppenauer, *Rec. Trav. chim.*, 1937, **56**, 137. [8] Heilbron, Spring, and Stewart, *J.*, 1935, 1221. [9] Honigmann, *Annalen*, 1934, **508**, 89. [10] *J.*, 1952, 4883. [11] Callow, *Biochem. J.*, 1931, **25**, 79. [12] Bills and Honeywell, *J. Biol. Chem.*, 1928, **80**, 15.

for the pair and that of either *neo*ergosterol (XXXIII; R = H) {($[M]_D$ −42° (Bonstedt, *Z. physiol. Chem.*, 1929, **185**, 165)} (pairs 2 and 7) or *neo*ergostapentaene (XXXIV) {($[M]_D$ +185° (EtOH) (Cook and Haslewood, *Chem. and Ind.*, 1934, **53**, 507)} (pairs 1 and 3). In making these calculations the acetylation increment for *neo*ergosterol is neglected; it is probably small [cf. the acetylation increment for *epi-neo*ergosterol $\Delta[M]_D$ −12° (Windaus and Deppe, *Ber.*, 1937, **70**, 76)].



(XXXIII)



(XXXIV)

EXPERIMENTAL

M. p.s were determined on a Kofler hot stage. Unless otherwise stated, rotations were determined on chloroform solutions at room temperature (18—25°) in a 1-dm. tube, ultraviolet spectra were determined on solutions in specially purified ethanol (Bladon, Henbest, and Wood,

J., 1952, 2737) by use of Unicam SP 500 spectrophotometers, and infrared spectra on Nujol mulls with a Perkin-Elmer model 21 double-beam instrument with sodium chloride optics.

Alumina (Spence Type "H" or Type "O") was deactivated by the method of Farrar, Hamlet, Henbest, and Jones (*J.*, 1952, 2657). Light petroleum had b. p. 60—80°.

The lumisteryl 3 : 5-dinitrobenzoate used had m. p. 139—142°; hydrolysis with aqueous ethanolic potassium hydroxide gave lumisterol, m. p. 116—118°, $[\alpha]_D$ +187° (*c*, 1·3), +187° (*c*, 0·85 in $COMe_2$), $\lambda_{max.}$ 272—273 (ε 9053) and 280 mμ (ε 8486). Acetylation of the sterol with acetic anhydride and pyridine gave the acetate, m. p. 100·5—102°, $[\alpha]_D$ +131° (*c*, 0·93); $\lambda_{max.}$ 271—273 (ε 8920) and 280 mμ (ε 8460). The sterol deteriorated slowly, but the acetate was more stable.

(*A*) *Photo-oxidation Experiments.*—(a) *Lumisteryl acetate in refluxing ethanol.* Lumisteryl acetate (20 g.), pyridine (4 c.c.), eosin [50 c.c. of a filtered solution of the dye (1 g.) in ethanol (100 c.c.)], and ethanol (1250 c.c.) were irradiated from beneath by a 300-watt incandescent lamp (the heat causing the solution to reflux gently), while oxygen (8—11 l./hr.) was bubbled through the solution for 16 hr. The course of the reaction was followed spectrophotometrically on withdrawn samples. The solution was evaporated under reduced pressure and the residue triturated with warm methanol. The solid obtained on cooling was dissolved in ether and methylene chloride and treated with alumina (*ca.* 50 g.; small portions) until the solution was colourless. The filtered solution was evaporated and the residue crystallised twice from acetone yielding feathery needles (3·5 g.), m. p. 155—157°, $[\alpha]_D$ +42° (*c*, 1·215). Evaporation of the mother liquors gave a solid (5·1 g.). The properties of the recrystallised material agreed with those of the pure lumisteryl acetate epidioxide ultimately obtained. However, discrepancies in the constants for different preparations suggested that it was impure. Accordingly, the crystalline material (material I) in light petroleum and benzene mixture (1 : 1; 200 c.c.), and the residue from the mother liquors (material II) in light petroleum (200 c.c.) were separately chromatographed on alumina (700 g. and 200 g., respectively). The chromatograms were eluted with light petroleum, benzene, ether, and methanol, and mixtures of these solvents, to give the following fractions (rotations measured in methylene chloride).

Material I: I*a*, $[\alpha]_D$ +252°; I*b*, $[\alpha]_D$ −9°; I*c*, $[\alpha]_D$ +30°; I*d*, $[\alpha]_D$ +41° to +56°; I*e*, $[\alpha]_D$ +61° to +72°; I*f*, $[\alpha]_D$ +26°.

Material II: II*a*, $[\alpha]_D$ +143° to +217°; II*d*, $[\alpha]_D$ +84° to +46°; II*e*, $[\alpha]_D$ +74·5° to +83·5°; II*g*, −31·3° to −47·5°; II*h*, $[\alpha]_D$ +40° to +44°; II*j*, $[\alpha]_D$ −7·4°.

Treatment of Bulked Fractions from the Chromatograms.—Fractions I*a* and II*a* after several crystallisations from ethyl acetate yielded needles of dehydrolumisteryl acetate (II), m. p. and mixed m. p. 141—144°, $[\alpha]_D$ +229° (*c*, 0·72). An authentic specimen prepared by Heilbron, Spring, and Stewart's method (*J.*, 1935, 1221), had m. p. 143—146°, $[\alpha]_D$ +236° (*c*, 1·55), $\lambda_{max.}$ 309—312 (ε 10,100) and 319—320 mμ (ε 10,800), and had an identical infrared spectrum (Found: C, 82·55; H, 9·95. Calc. for $C_{30}H_{44}O_2$: C, 82·5; H, 10·15%).

Fraction I*b* yielded needles (108 mg.; from acetone) of 3β-*acetoxy*-5β : 8β-*epidioxylumista*-6 : 9(11) : 22-*triene* (*dehydrolumisteryl acetate* β-*epidioxide*) (III; R = Ac), m. p. 178—180°, $[\alpha]_D$ −10·4° (*c*, 0·49) (Found: C, 76·85; H, 9·5. $C_{30}H_{44}O_4$ requires C, 76·9; H, 9·5%).

Fraction I*c* gave needles (270 mg.; from acetone), m. p. 165—167°, $[\alpha]_D$ +33·4° (*c*, 0·77), identified by alkali treatment (see below) as a mixture of the β-epidioxides of dehydrolumisteryl acetate (III; R = Ac) and lumisteryl acetate (IV; R = Ac) (Found: C, 76·2; H, 9·8%).

Fractions I*d* (4 subfractions) gave 3β-*acetoxy*-5β : 8β-*epidioxylumista*-6 : 22-*diene* (*lumisteryl acetate* β-*epidioxide*) (IV; R = Ac) (total yield, 1·948 g.; from acetone), m. p. 156—159°, 157—158°, 154—156°, 157—158°, $[\alpha]_D$ +46·3° (*c*, 0·62), +45·5° (*c*, 0·99), +45·8° (*c*, 0·88), +49·1° (*c*, 0·735) (Found: C, 76·7; 76·65; 76·75; 76·95; H, 9·65, 10·0, 9·95, 9·9. $C_{30}H_{46}O_4$ requires C, 76·55; H, 9·85%). All samples showed identical infrared spectra. On prolonged heating above its first melting point this compound solidified at about 160° to rosettes remelting at 169—172°.

Fraction II*d* gave impure lumisteryl acetate β-epidioxide, m. p. 157—159° (475 mg.; thrice from acetone), $[\alpha]_D$ +35·2° (*c*, 1·665) (Found: C, 76·85; H, 9·85%).

Fraction I*e* gave, on crystallisation from acetone and ether–methanol, needles (103 mg.), m. p. 152—155°, $[\alpha]_D$ +54·6° (*c*, 0·52) (Found: C, 79·95; H, 10·0%), which were probably impure lumisteryl acetate β-epidioxide.

Fraction II*e* had m. p. 145—170° even after four recrystallisations from acetone; it was probably a mixture of lumisteryl acetate β-epidioxide and dehydrolumisteryl acetate α-epidioxide.

Fraction II*g* gave 3β-*acetoxylumista*-5 : 8(9) : 22-*trien*-7-*one* (VI; R = Ac), needles (77 mg.;

second crop, 120 mg.) (from *iso*propyl ether), m. p. 179—182°, $[\alpha]_D$ −93·8° (*c*, 0·82) (Found: C, 79·7; H, 9·8. $C_{30}H_{44}O_3$ requires C, 79·6; H, 9·8%). Light absorption: $\lambda_{max.}$ 246 mμ, ε 11,800. Infrared spectrum (in Nujol): $\nu_{max.}$ 1725 s (OAc); 1663 s, 1631 s, 1597 m, (C:C·CO·C:C); 1250 s (OAc), 987 m (−C:C·CO·C:C) (see also Table 2).

Fractions I*f*, II*h*, and II*j* were not examined.

(b) *Lumisteryl acetate in ethanol at room temperature.* Lumisteryl acetate (5 g.) in ethanol (400 c.c.), ethanolic eosin [100 c.c.; as described in (a)], and pyridine (2·5 c.c.) were contained in a vertical Pyrex glass tube (70 cm. × 3·8 cm.) sealed at the lower end. Oxygen (4—6 l./hr.) was passed through the solution from the bottom, and the tube was irradiated by a 40 w "natural" type fluorescent tube, the distance between the centres of the reaction tube and the fluorescent tube being 7 cm. Oxygen flow and irradiation were continued for 24 hr.; by then the lumisteryl acetate concentration had been reduced by *ca.* 90%, as measured spectrographically. Solid separated from the mixture towards the end. The mixture was evaporated to dryness under reduced pressure, benzene being added towards the end. A solution of the residue in benzene (200 c.c.) was filtered on to alumina (500 g.), and the column eluted with benzene and ultimately with ether to give the following fractions (in order of elution).

Fraction III*a* ($[\alpha]_D$ +222°), giving needles of dehydrolumisteryl acetate (II) (420 mg.) (from ethyl acetate), m. p. 140—142°.

Fraction III*d* ($[\alpha]_D$ +52·5° to +43·5°), lumisteryl acetate β-epidioxide (IV; R = Ac) (1835 mg.; needles from acetone), m. p. 155—159°, $[\alpha]_D$ +48·5°.

Fraction III*g* ($[\alpha]_D$ −15° to −50°), 3β-acetoxylumista-5 : 8 : 22-trien-7-one (VI; R = Ac) (377 mg.; from *iso*propyl ether), m. p. 175—181°.

The above chromatogram is typical of many that were run. Increase in the quantity of alumina (to 1500 g.) allowed a sharper separation of the various fractions, but did not increase the final yields. Use of alumina which had not been deactivated caused extensive deacetylation and rearrangement of the peroxide. The dehydrolumisteryl acetate was eluted with benzene, but further elution with benzene did not give more material. Benzene–ether mixtures eluted materials having high rotations ($[\alpha]_D$ +60° to +100°). Finally, elution with 9 : 1 ether–methanol gave 5β : 8β-*epidioxy*-3β-*hydroxylumista*-6 : 22-*diene* (IV; R = H), leaflets (from methanol), m. p. 142—144°, $[\alpha]_D$ +72·7° (*c*, 0·73) (Found: C, 78·55; H, 10·4. $C_{28}H_{44}O_3$ requires C, 78·45; H, 10·35%). $\nu_{max.}$ (in Nujol) 3520 m (OH), 1635 w (Δ^6), and 983 m cm.$^{-1}$ (Δ^{22}). Acetylation gave the 3β-acetate as needles (from acetone), m. p. 150—153°, $[\alpha]_D$ +47·5° (*c*, 0·65) (Found: C, 76·8; H, 10·0. Calc. for $C_{30}H_{46}O_4$: C, 76·55; H, 9·85%). The infrared spectrum was identical with that of material from fraction I*d*.

(c) *Dehydrolumisteryl acetate in refluxing ethanol.* Dehydrolumisteryl acetate (500 mg.), ethanol (37·5 c.c.), pyridine (0·25 c.c.), and ethanolic eosin [12·5 c.c.; prepared as described in (a)] were irradiated in oxygen as in (a) (flow rate, 5 l./hr.; 300-watt incandescent lamp) for 9·5 hr. Spectrographic examination showed that the reaction was nearly complete after 3·5 hr. The mixture was evaporated to dryness under reduced pressure, and the residue was chromatographed in light petroleum–benzene (3 : 2; 200 c.c.) on alumina (100 g.), giving: (i) Dehydrolumisteryl acetate β-epidioxide (III; R = Ac) (from acetone–methanol), m. p. 178—179°, $[\alpha]_D$ −7·6° (Found: C, 77·0; H, 9·8. Calc. for $C_{30}H_{44}O_4$: C, 76·9; H, 9·5%); this material had an infrared spectrum identical with the material from fraction I*b*. (ii) 3β-*Acetoxy*-5α : 8α-*epidioxylumista*-6 : 9(11) : 22-*triene* (*dehydrolumisteryl acetate α-epidioxide*) (V; R = Ac), plates (from acetone–methanol), m. p. 164—166°, $[\alpha]_D$ +76·7° (*c*, 0·43) (Found: C, 76·8; H, 9·9. $C_{30}H_{44}O_4$ requires C, 76·9; H, 9·5%).

(d) *Dehydrolumisteryl acetate at room temperature.* Dehydrolumisteryl acetate (1·5 g.) in ethanol (400 c.c.), pyridine (2·5 c.c.), and eosin (100 c.c. of nominal 1% solution) was irradiated and oxygenated in the apparatus described in (b) for 21 hr. (oxygen rate, 4—5 l./hr.). The solution was evaporated to dryness under reduced pressure and the residue was chromatographed on alumina (200 g.). No clean separation of the two epidioxides was observed even when the epidioxide fractions (all solid; eluted with benzene; 1·34 g., $[\alpha]_D$ +54° to +70°) were rechromatographed. Fractional crystallisation of the mixture from ethanol gave dehydrolumisteryl acetate α-epidioxide (V; R = Ac) as needles (427 mg.), m. p. 166—169°, $[\alpha]_D$ +76·2° (*c*, 1·11), +79·5° (*c*, 0·83) (Found: C, 76·7; H, 9·25. Calc. for $C_{30}H_{44}O_4$: C, 76·9; H, 9·5%). This sample had higher m. p. and different crystal form from that described in (c) (ii) above; however, the m. p.s were not depressed when the samples were mixed, and the infrared spectra (Nujol mulls) were identical.

Material (920 mg.) from the mother liquors was refluxed in ethanol (20 c.c.) with potassium hydroxide (1 g.) in water (5 c.c.) for 1 hr. Acidification with concentrated hydrochloric acid and

extraction with ether gave a brownish product which was chromatographed in benzene on alumina (100 g.). Benzene eluted traces of oil; benzene–ether (9 : 1) gave a fraction (IV*a*; 113 mg.; for the examination of this material see section *D*). Benzene–ether (4 : 1 and 1 : 1) eluted material (IV*b*; 405 mg.) which after three recrystallisations from acetone–methanol gave 5α : 8α-*epidioxy*-3β-*hydroxylumista*-6 : 9(11) : 22-*triene* (V; R = H) (28 mg.), m. p. 155—157°, $[\alpha]_D$ +70·1° (*c*, 0·525) (Found: C, 78·4; H, 9·7. $C_{28}H_{42}O_3$ requires C, 78·8; H, 9·9%). The poor yield is due to the instability of the compound in methanolic solution.

Hydrolysis of the acetate α-epidioxide (20 mg.) gave a poor yield of the 3-hydroxy-compound, m. p. and mixed m. p. 148—153° $[\alpha]_D$ +70° (*c*, 0·1), having an infrared spectrum identical with the sample described above.

(*B*) *Lumisteryl Acetate* β-*Epidioxide*.—8β-*Hydroxylumista*-4 : 6 : 22-*trien*-3-*one* (XX). Lumisteryl acetate β-epidioxide (500 mg.) in ethanol (20 c.c.) and potassium hydroxide (1 g.) in water (5 c.c.) were heated under reflux for 2·5 hr. After cooling, the product was extracted with ether; concentration of the extract and treatment of the residue with methanol gave a solid (451 mg.), which (520 mg.) was chromatographed in benzene on alumina (50 g.). Benzene eluted traces of oil; benzene–ether (9 : 1 to 1 : 1) eluted material (460 mg.) from which was obtained 8β-*hydroxylumista*-4 : 6 : 22-*trien*-3-*one*, pale cream needles, m. p. 137—140°, $[\alpha]_D$ −377° (*c*, 0·45), −354° (*c*, 0·38 in MeOH) (Found: C, 80·6; H, 10·4. $C_{28}H_{42}O_2$,0·5MeOH requires C, 80·3; H, 10·4%), $\lambda_{max.}$ 283—285 mμ (ε 26,600). A satisfactory analysis for the unsolvated material was obtained only after sublimation at 170—190°/10^{-4} mm., which process did not remove the hydroxyl group. The sublimed material had m. p. 125—130°, resolidifying to hair-like needles, m. p. 142—145° (Found: C, 82·1; H, 10·35. $C_{28}H_{42}O_2$ requires C, 81·9; H, 10·3%), $\lambda_{max.}$ 282—283 mμ (ε 25,600). The compound was unchanged when left overnight with acetic anhydride and pyridine.

Lumista-4 : 6 : 8(14) : 22-*tetraen*-3-*one* (XXI). (*a*) Lumisterol (5 g.), benzoquinone (10 g.; recrystallised from light petroleum), and dry toluene (60 c.c.) were distilled until water had been eliminated by entrainment, a solution of aluminium *tert.*-butoxide (10 g.) in toluene (50 c.c.) was added, and the mixture was refluxed for 50 min. The black solid was filtered off and washed with hot benzene. The filtrates were washed with dilute sulphuric acid, and aqueous potassium hydroxide, and aqueous ammonium sulphate, dried (Na_2SO_4), and concentrated to a dark red gum (2·5 g.). This was chromatographed in benzene (100 c.c.) on alumina (100 g.), benzene being used as eluant. The first 300 c.c. eluted only red oil. The next 350 c.c. eluted material which was rechromatographed on alumina in light petroleum. Elution of this chromatogram with light petroleum (460 c.c.) gave needles, m. p. 80—86° (252 mg., 5%; from methanol). Further recrystallisation gave *lumista*-4 : 6 : 8(14) : 22-*tetraen*-3-*one*, (XXI) as pale yellow needles, m. p. 86—88°, $[\alpha]_D$ −767° (*c*, 0·505), −740° (*c*, 0·53 in MeOH) (Found: C, 85·7; H, 10·2. $C_{28}H_{40}O$ requires C, 85·65; H, 10·3%); $\lambda_{max.}$ 285 (ε 8170), 350—358 mμ (ε 25,500). This compound gave a yellow solution with a green fluorescence when treated with perchloric acid in methanol.

(*b*) 8β-Hydroxylumista-4 : 6 : 22-trien-3-one (37 mg.) in methanol (3 c.c.) was treated with perchloric acid (60% aqueous solution; 2 drops). The solution became yellow with a green fluorescence, $[\alpha]_D$ changing from −354° to −715° during 50 min. It was set aside for 1 hr. and then diluted with water, and the product (36 mg.) isolated by ether extraction. The pale yellow needles (from methanol) of the tetraenone had m. p. 86—89°, undepressed with material prepared as in (*a*), $[\alpha]_D$ −781° (*c*, 0·64), $\lambda_{max.}$ 284—286 (ε 7950), 354—358 mμ (ε 24,300). The infrared spectra (in Nujol) of the two samples were identical.

Lumista-4 : 6 : 8(14) : 22-*tetraen*-3-*one* 2 : 4-*dinitrophenylhydrazone*, prepared from the parent ketone or from 8β-hydroxylumista-4 : 6 : 22-trien-3-one, formed deep red plates, m. p. 264—265° (sintering 200°) (Found: C, 71·15; H, 7·9; N, 9·75. $C_{34}H_{44}O_4N_4$ requires C, 71·3; H, 7·7; N, 9·8%), $\lambda_{max.}$ 267·5 (ε 15,200), 335 (ε 16,400), 350 (ε 16,000), and 427·5 mμ (ε 42,450) in chloroform.

Lumista-4 : 6 : 8(9) : 22-*tetraen*-3-*one* (XXII). 8β-Hydroxylumista-4 : 6 : 22-trien-3-one (110 mg.) was refluxed with pyridine (4 c.c.) and acetic anhydride (4 c.c.) for 2 hr. in an atmosphere of carbon dioxide. The excess of reagents was removed *in vacuo* and the residue chromatographed in light petroleum on alumina. The material (90 mg.) eluted with petroleum–benzene gave greenish-yellow plates (from acetone) of *lumista*-4 : 6 : 8(9) : 22-*tetraen*-3-*one*, m. p. 134—137° (depressed to 100—110° on admixture with starting material), $[\alpha]_D$ −822° (*c*, 0·415) (Found: C, 85·75; H, 10·2. $C_{28}H_{40}O$ requires C, 85·65; H, 10·3%), $\lambda_{max.}$ 244 (ε 17,900) and 393 mμ (ε 11,000).

3β-*Acetoxylumistane*-5β : 8β-*diol* (XXVII; R = Ac). Lumisteryl acetate β-epidioxide

(600 mg.) in ethyl acetate (50 c.c.) was shaken with pre-reduced platinum oxide catalyst (Adams's; 100 mg.) and hydrogen until absorption ceased (uptake, 103 c.c. at 772 mm. and 23·5°; calc. for 3 moles, 102 c.c.). The residue obtained on removal of the solvent was absorbed from light petroleum (80 c.c.) on alumina (60 g.). Elution with light petroleum, light petroleum–benzene (1 : 1) (600 c.c.), and benzene (400 c.c.) and crystallisation (twice) from acetone yielded 3β-*acetoxylumistane*-5β : 8β-*diol* (468 mg.) as plates, m. p. 173—175°, $[\alpha]_D$ +89·5° (*c*, 0·415) (Found: C, 75·6; H, 10·9. $C_{30}H_{52}O_4$ requires C, 75·6; H, 11·0%); $\nu_{max.}$ 3545 m and 3320 ms (both sharp peaks; OH groups), 1720 s (OAc), 1297 s, 1270 s, 1251 s, 1220 s (axial OAc), 1075 m 1055 w, 1039 m, 1020 m, and 1000 m (OH groups) cm.$^{-1}$ in Nujol. In subsequent preparations chromatography was dispensed with; crystallisation of the product (from 700 mg. of epidioxide) gave the diol, m. p. 170—175°, $[\alpha]_D$ +91° (*c*, 0·91) (534 mg.; 73·5%). Crystallisation of the diol from methanol gave needles, m. p. 150—173° with accompanying change of crystal form to plates. No chemical change had taken place for subsequent crystallisation from acetone gave plates, m. p. 170—175°. This property is attributed to the formation of a low-melting needle form which only slowly changes into the plate form on heating.

In an earlier experiment, epidioxide (300 mg.) yielded on chromatography a preliminary fraction (96 mg.) easily eluted with benzene. This was slightly impure 3β-acetoxylumist-7-en-5β-ol (XXVIII) (see below) forming needles (from methanol), m. p. 136—139°, $[\alpha]_D$ +43·5°. (Infrared spectrum was similar to that of the pure material.) Further elution gave the 3β-acetoxy-diol. This result is difficult to explain in view of the stability of the diol.

Lumistane-3β : 5β : 8β-*triol* (XXVII; R = H). The above diol monoacetate (100 mg.) was refluxed with potassium hydroxide (500 mg.) in ethanol (20 c.c.) and water (5 c.c.) for 2·5 hr. After adding water and cooling, the solid was filtered off (85 mg.), m. p. 213—220°. *Lumistan*-3β : 5β : 8β-*triol* formed needles (from methanol), m. p. 215—221° with sublimation at 210°, $[\alpha]_D$ +97° (*c*, 0·65) (Found: C, 77·7; H, 11·65. $C_{28}H_{50}O_3$ requires C, 77·35; H, 11·6%); $\nu_{max.}$ 3325 and 3340 cm.$^{-1}$ (hydroxy bands) in Nujol. The triol was reacetylated to the diol monoacetate, m. p. and mixed m. p. 170—175°, $[\alpha]_D$ +92·6° (*c*, 0·75), possessing an infrared spectrum identical with that of an authentic specimen.

3β-*Acetoxylumist*-7-*en*-5β-*ol* (XXVIII). Refluxing of 3β-acetoxylumistane-5β : 8β-diol with acetone–acetic acid (19 : 1) for 3 hr. led to quantitative recovery of material; more acidic conditions and higher temperature led to dehydration. The diol monoacetate (300 mg.) was heated with glacial acetic acid on the steam-bath for 2 hr. Evaporation under reduced pressure gave an oil which was chromatographed in light petroleum on alumina (25 g.). Elution with light petroleum–benzene (500 c.c.) yielded oily material (105 mg.). Elution with benzene (300 c.c.) and crystallisation from methanol gave needles (36 mg.) of 3β-*acetoxylumist*-7-*en*-5β-*ol*, m. p. 138—141°, $[\alpha]_D$ +30·4 (*c*, 0·74) (Found: C, 78·8; H, 10·95. $C_{30}H_{50}O_3$ requires C, 78·55; H, 11·0%); $\nu_{max.}$ 3550 (OH), 1730 s (OAc), 1297 w, 1259, 1235 s, and 1210 m cm.$^{-1}$ (all axial OAc) in Nujol.

(*C*) *Dehydrolumisteryl Acetate α-Epidioxide.—Hydrogenation of dehydrolumisteryl* 5α : 8α-*epidioxide acetate*. (*a*) The epidioxide (70 mg.) in ethyl acetate (12·5 c.c.) was hydrogenated in the presence of pre-reduced platinum oxide (Adams's; 50 mg.) until absorption became slow (15 min.; 8·2 c.c. at 763 mm. and 23°. Calc. for 3 moles; 10·7 c.c.). The syrupy residue was dissolved in methanol (1 c.c.) at 60° and treated with concentrated hydrochloric acid (2 drops) for 2 min. Cooling, addition of water, ether extraction of the precipitate, and crystallisation from aqueous methanol gave 3β-*acetoxylumista*-7 : 9(11)-*dien*-5α-*ol* (XXX; R = Ac), hard granules, apparently isotropic, m. p. 155—158°, $[\alpha]_D$ +71·7° (*c*, 0·58) (Found: C, 79·0; H, 10·7. $C_{30}H_{48}O_3$ requires C, 78·9; H, 10·6%); $\lambda_{max.}$ 241 mμ (ε 17,300), $\lambda_{infl.}$ 235—236 mμ (ε 15,870). Hydrolysis of the material in the mother-liquors gave *lumista*-7 : 9(11)-*diene*-3β : 5α-*diol* (XXX; R = H) as plates (from methylene chloride–methanol), m. p. 255—263° (decomp.; change of form to needles at 220—230°), $[\alpha]_D$ +101° (*c*, 0·3 in C_5H_5N) (Found: C, 81·65; H, 11·3. $C_{28}H_{46}O_2$ requires C, 81·1; H, 11·2%); $\lambda_{max.}$ 240 mμ (ε 13,350), $\lambda_{infl.}$ 234·5 mμ (ε 12,400). This compound was sparingly soluble in most solvents and separated as a gel unless methanol was present.

(*b*) The epidioxide (300 mg.) in ethyl acetate (25 c.c.) was hydrogenated in the presence of pre-reduced platinum oxide (Adams's; 100 mg.) until absorption ceased (1·5 hr.; 57 c.c. absorbed at 742 mm. and 22°. Calc. for 4 moles, 62 c.c.). Several recrystallisations of the residue from methanol gave 3β-*acetoxy*-9β-*lumist*-7-*en*-5α-*ol* (XXXI; R = Ac) as needles (37 mg.), m. p. 147—148·5°, $[\alpha]_D$ −40·3° (*c*, 0·72) (Found: C, 78·8; H, 10·7. $C_{30}H_{50}O_3$ requires C, 78·55; H, 11·0%); $\nu_{max.}$ 3500 m (OH), 1716 s (OAc), and 1283 s cm.$^{-1}$ (equatorial OAc) in Nujol.

9β-*Lumist*-7-*ene*-3β : 5α-*diol* (XXXI; R = H). The above acetate (65 mg.) was refluxed with potassium hydroxide (200 mg.) in water (0·25 c.c.), methanol (3 c.c.), and dioxan (3 c.c.) for 45 min., and the mixture then cooled, diluted, and extracted with methylene chloride. Crystallisation from methanol and then from tetrahydrofuran–methanol afforded 9β-*lumist*-7-*enc*-3β : 5α-*diol* as plates changing to needles at *ca.* 200°, m. p. 231—237°, $[\alpha]_D$ +33·6° (*c*, 0·53 in C_5H_5N) (Found, on material sublimed at 200°/10^{-6} mm.: C, 80·35; H, 11·2. $C_{28}H_{48}O_2$ requires C, 80·7; H, 11·6%). This material is characterised by relative insolubility in organic solvents; it tended to separate from hot solvent as a gel, unless methanol was present.

(*D*) *Dehydrolumisteryl Acetate* β-*Epidioxide.—Action of alkali on dehydrolumisteryl acetate* β-*epidioxide* (III; R = Ac). The epidioxide (93 mg.) in ethanol (10 c.c.) and potassium hydroxide (0·5 g.) in water (2·5 c.c.) were refluxed for 2 hr., then cooled, diluted with water, and extracted with ether. The ethereal extract was washed with water and aqueous potassium hydrogen carbonate, dried, and evaporated. The residual red oil (88 mg.) was chromatographed in light petroleum on alumina (10 g.); elution with light petroleum–benzene mixture and with benzene gave oily material (21 mg.), benzene–ether (9 : 1) eluted a syrupy material (48 mg.) which would not crystallise, and further elution gave only traces of non-crystalline material. The material eluted by benzene–ether was probably impure 8β-hydroxylumista-4 : 6 : 9(11) : 22-tetraen-3-one (XXV). It had $[\alpha]_D$ −344° (initial) ⟶ −209° (1 hr.) (*c*, 0·48 in CH_2Cl_2); $\lambda_{max.}$ 285—286 mμ (ε 14,300). When perchloric acid (1 drop) was added to the spectrographic solution the spectrum changed (24 hr.) to $\lambda_{max.}$ 296 (ε 13,450) and 385 mμ (ε 10,500). On the basis of these values and those of the pure pentaenone (see below) the 8β-hydroxy-ketone was 81·5% pure. The calculated value of the maximal extinction coefficient of the pure 8β-hydroxy-ketone is then 17,600.

Evaporation of the methylene chloride solution used in the determination of the rotation gave a yellow oil which rapidly solidified. To ensure complete dehydration it was dissolved in methanol (2 c.c.), and aqueous perchloric acid (60%; 2 drops) added. The red solution was then immediately worked up and gave *lumista*-4 : 6 : 8(14) : 9(11) : 22-*pentaen*-3-*one* (XXVI) (46 mg.) as bright yellow prisms (16 mg.), m. p. 142—145° (from methanol), $[\alpha]_D$ −285° (*c*, 0·56) (Found: C, 86·15; H, 9·7. $C_{28}H_{38}O$ requires C, 86·1; H, 9·8%); $\lambda_{max.}$ 300 (ε 16,300) and 385—386 mμ (ε 13,100).

Fraction IV*a* (see above) after three recrystallisations from methanol gave more lumista-4 : 6 : 8(14) : 9(11) : 22-pentaen-3-one (40 mg.), m. p. 142—145°, $[\alpha]_D$ −279° (*c*, 0·5).

(*E*) 3β-*Acetoxylumista*-5 : 8(9) : 22-*trien*-7-*one* (VI; R = Ac).—*Hydrolysis of* 3β-*acetoxy-lumista*-5 : 8(9) : 22-*trien*-7-*one*. The ketone (220 mg.) in ethanol (15 c.c.) was treated with potassium hydroxide (1 g.) in water (1 c.c.) and ethanol (5 c.c.), and set aside at room temperature overnight. Dilute hydrochloric acid was then added and the precipitate washed with water and dried (206 mg.). Crystallisation from acetone gave 3β-*hydroxylumista*-5 : 8(9) : 22-*trien*-7-*one*, as plates, m. p. 233—237° (decomp.; change of form below m. p.), $[\alpha]_D$ −93·0° (*c*, 0·71), −93·5° (*c*, 0·43) (Found: C, 81·85; H, 10·45. $C_{28}H_{42}O_2$ requires C, 81·9; H, 10·3%), $\lambda_{max.}$ 250 mμ (ε 12,800), $\nu_{max.}$ 3365 (OH), 1652 s, 1600 s, 1605 sh, and 875 m cm.$^{-1}$ (C:C–CO–C:C). Acetylation with acetic anhydride and pyridine at room temperature overnight gave the 3β-acetate, m. p. and mixed m. p. 180—183°, having infrared spectrum identical with that of authentic material. The residue obtained on evaporation of the mother liquor from the hydrolysis (132 mg.; $[\alpha]_D$ −20° in methylene chloride) was refluxed with potassium hydroxide (1 g.) in ethanol (5 c.c.) and water (1 c.c.) for 2·5 hr. Working up gave a dark red oil (101 mg.) which was dissolved in benzene (100 c.c.) and passed through alumina (10 g.). Evaporation of the eluates gave a solid (61 mg.) which yielded *lumista*-3 : 5 : 8(9) : 22-*tetraen*-7-*one* (VIII) as plates (acetone–methanol), m. p. 172—174° (change of form to needles below the m. p.), $[\alpha]_D$ +83·6° (*c*, 0·495) (Found: C, 85·6; H, 10·2. $C_{28}H_{40}O$ requires C, 85·65; H, 10·3%); $\lambda_{max.}$ 272—273 mμ (ε 13,800), $\lambda_{infl.}$ 302—305 mμ (ε 8100), $\nu_{max.}$ 1639 s, 1605 m, 1589 m, and 880 s cm.$^{-1}$ (–C:C–C:C–CO–C:C–) in Nujol (see below).

The same material was obtained from the hydrolysis of the mother liquors from the crystallisations of 3β-acetoxylumista-5 : 8(9) : 22-trien-7-one and of lumisteryl acetate β-epidioxide.

Treatment of 3β-*acetoxylumista*-5 : 8(9) : 22-*trien*-7-*one with zinc, acetic acid, and silver nitrate*. The ketone (100 mg.) was refluxed with zinc dust (1 g.) and silver nitrate (100 mg.) in acetic acid (5 c.c.) for 1 hr. The zinc was filtered off and washed with methylene chloride, and the filtrates extracted with ether. Evaporation of the extracts, dissolution of the residue (100 mg.) in 2 : 1 light petroleum–benzene (30 c.c.), chromatography on alumina (10 g.) and elution, first with light petroleum–benzene (oily material) and then with benzene, gave (?)-*acetoxyanthraergosta*-5 : 7 : 9 : 22-*tetraen*-7-*ol* (VII) as flakes (from acetone), m. p. 215—218° (with change to needles

below m. p.), $[\alpha]_D$ −38° (*c*, 0·39) (Found: C, 79·5; H, 9·75. $C_{30}H_{44}O_3$ requires C, 79·6; H, 9·8%); $\lambda_{max.}$ (at pH 7) 290 mμ (ε 2930), $\lambda_{max.}$ (at pH 9·5) 304—306 mμ (ε 3600); $\nu_{max.}$ 3445 s (OH), 1710 s (OAc), 1600 m and 1589 m (phenol), 1267 s (OAc), and 828 m cm.$^{-1}$ (Δ^{22}). This material was not soluble in aqueous potassium hydroxide and did not colour aqueous or ethanolic ferric chloride.

3β-*Acetoxyergosta*-5 : 8(9)-*dien*-7-*one* (X). 3β : 11α-Diacetoxyergosta-5 : 8(9)-dien-7-one (500 mg.) was heated with zinc dust (1 g.), glacial acetic acid (20 c.c.), and a few drops of aqueous silver nitrate for 1 hr. The zinc was filtered off and the product (500 mg. crude) crystallised from acetone–methanol, affording plates of 3β-*acetoxyergosta*-5 : 8(9)-*dien*-7-*one*, m. p. 185—186°, $[\alpha]_D$ −40·7° (*c*, 0·935), −39·7° (*c*, 0·59) (Found: C, 79·0; H, 10·2. $C_{30}H_{46}O_3$ requires C, 79·25; H, 10·2%); $\lambda_{max.}$ 244 mμ (ε 11,600); $\nu_{max.}$ 1728 s (OAc), 1664 s, 1630 ms, 1596 mw (all C=C–CO–C=C), and 1267 s cm.$^{-1}$ (OAc) in Nujol.

(?)-*Acetoxyanthraergosta*-5 : 7 : 9-*trien*-7-*ol* (XI). (*a*) 3β-Acetoxyergosta-5 : 8(9)-dien-7-one (200 mg.), zinc dust (1 g.), silver nitrate (230 mg.), and acetic acid (10 c.c.) were refluxed for 0·5 hr. More (1 g.) zinc was added and refluxing continued for a further 0·5 hr. The product was chromatographed on alumina (10 g.); benzene eluted (?)-*acetoxyanthraergosta*-5 : 7 : 9-*trien*-7-*ol* (32 mg.), which formed flakes, m. p. 210—215°, $[\alpha]_D$ −31·5° (*c*, 0·385) (Found: C, 79·45; H, 10·25. $C_{30}H_{46}O_3$ requires C, 79·25; H, 10·2%); $\lambda_{max.}$ (at pH 7) 288—289 mμ (ε 2785), $\lambda_{max.}$ (at pH 9·5) 304 mμ (ε 3260); $\nu_{max.}$ 3440 s (OH), 1714 s (OAc), 1602 m and 1592 m (phenol), and 1269 s cm.$^{-1}$ (OAc) in Nujol.

(*b*) (?)-Acetoxyanthraergosta-5 : 7 : 9 : 22-tetraen-7-ol (11 mg.) and Adams's platinum oxide catalyst (50 mg.), in ethyl acetate (10 c.c.), were shaken in hydrogen for 1 hr. Isolation of the product gave (?)-acetoxyanthraergosta-5 : 7 : 9-trien-7-ol as flakes, m. p. 210—213° undepressed on admixture with material prepared as in (*a*), $[\alpha]_D$ −26° (*c*, 0·43). The identity of the samples prepared in (*a*) and (*b*) was confirmed by their identical infrared spectra and the similar behaviour of their solidified melts under the polarising microscope (observation kindly made by Dr. J. D. Bu'Lock).

Infrared Spectra of Ketones.—The spectra of seven of the ketones described above were determined in carbon disulphide at a concentration of 14 mg./c.c. and path length 2 mm. in the regions 1800—1500 and 1300—660 cm.$^{-1}$. The results are recorded in Table 2. Carbon disulphide absorbs strongly in the regions 1650—1400 and 900—800 cm.$^{-1}$ obscuring important peaks; results in these regions are taken from the routine spectra obtained as Nujol mulls (figures for these regions are in parentheses). All the compounds show strong absorption at maxima associated with the stretching vibrations in the conjugated carbonyl group (1670—

TABLE 2. *Infrared spectra of ketones in the lumisterol series.*

Compound	Wave-numbers of principal peaks (cm.$^{-1}$)
1. Lumista-4 : 7 : 22-trien-3-one	1674 s, (1621 m), 1273 mw, 1230 mw, 1195 w, 1160 w, 1140 vw, 1125 vw, 1675 vw, 1030 vw, 975 m, 960 w, (857 s), 825 w, 805 w, 765 w.
2. 8β-Hydroxylumista-4 : 6 : 22-trien-3-one	1667 s, (1627 s), (1580 m), 1295 w, 1275 m, 1230 m, 1200 mw, 1165 w, 1145 w, 1123 w, 1095 w, 1070 w, 1040 w, 1015 w, 995 m, 975 m, 947 m, 937 mw, 910 w, (885 s), 791 w, 770 w, 750 w, 730 w, 710 w, 675 w.
3. Lumista-4 : 6 : 8(14) : 22-tetraen-3-one	1663 s, (1635 w), (1590 s), 1299 w, 1270 m, 1230 m, 1215 mw, 1197 m, 1182 w, 1170 w, 1105 vw, 1070 vw, 1025 mw, 1010 vw, 975 m, 965 vw, (880 s), 800 w, 760 w, 695 w.
4. Lumista-4 : 6 : 8(9) : 22-tetraen-3-one	1655 s, (1575 m), (1550 m), 1275 mw, 1247 m, 1235 mw, 1197 mw, 1182 w, 1167 w, 1075 w, 1025 mw, 1007 w, 985 w, 974 m, 960 w, 957 m, 928 w, (869 s), 793 w, 773 w, 757 mw, 707 w, 680 w.
5. Lumista-4 : 6 : 8(14) : 9(11) : 22-pentaen-3-one	1660 s, (1590 s), (1565 w), 1287 w, 1260 m, 1233 ms, 1193 w, 1176 w, 1146 w, 1025 vw, 1030 w, 994 m, 975 m, 965 vw, 945 m, 930 m, (869 s), 815 w, 785 vw, 770 mw, 760 vw, 725 vw.
6. Lumista-3 : 5 : 8(9) : 22-tetraen-7-one	1643 s, (1605 m), (1589 m), 1275 mw, 1260 w, 1240 w, 1210 w, 1190 m, 1129 w, 1100 w, 1078 w, 1025 w, 985 mw, 973 m, 935 mw, (880 s), 778 w, 723 w, 685 w.
7. 3β-Acetoxylumista-5 : 8(9) : 22-trien-7-one	1736 s, 1663 s, (1631 s), (1597 m), 1275 sh, 1245 s, 1223 ms, 1207 ms, 1182 mw, 1151 mw, 1079 w, 1023 ms, 1003 w, 987 mw, 973 mw, 955 w, 930 w, 915 w, (890 w), (876 w), (847 mw), (835 mw), 756 w, 720 w, 685 w.

Abbreviations, which also apply to the text: s, strong; ms, medium strong; m, medium; mw, medium weak; w, weak; vw, very weak; sh, shoulder.

1580 cm.$^{-1}$) and all except No. 7 show a strong peak at about 880 cm.$^{-1}$ which is characteristic of αβ-unsaturated ketones (cf. Elks, *J.*, 1954, 468). The absence of such a strong peak in the cross-conjugated ketone (No. 7) is probably due to the symmetrical disposition of the double bonds about the ketone group. All the compounds have a maximum (975 cm.$^{-1}$) corresponding to the olefinic out-of-plane bending vibration of the side-chain double bond. Compound No. 7 shows maxima associated with the acetate group (1736, and groups in the regions 1275—1225 and 1020 cm.$^{-1}$). The other peaks cannot be identified with any certainty (but see the recent paper of R. N. Jones and Herling, *J. Org. Chem.*, 1954, **19**, 1252).

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