801. *Triterpenoids. Part XXII.* The Constitution and Stereochemistry of Masticadienonic Acid.†*

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The isolation of a new triterpenoid acid, masticadienonic acid, from gum mastic is reported. By degradation experiments this acid has been characterised as a derivative of tirucall-7-en-3β-ol. It contains a ketone grouping at the customary 3-position and has an αβ-unsaturated acid function at the terminus of the $C_{(8)}$-side chain. On the basis of this and other evidence the constitution and stereochemistry of the acid have been elucidated.

Although gum mastic has been an important article of commerce for centuries, its scientific chemistry has scarcely received consideration. Our own interest in this material was first stimulated by Mr. J. S. Mills of the National Gallery, who kindly informed us that it probably contained triterpenoid constituents.[1] We express our best thanks to Mr. Mills for this information and for his valuable advice in the initial stages of our investigation.

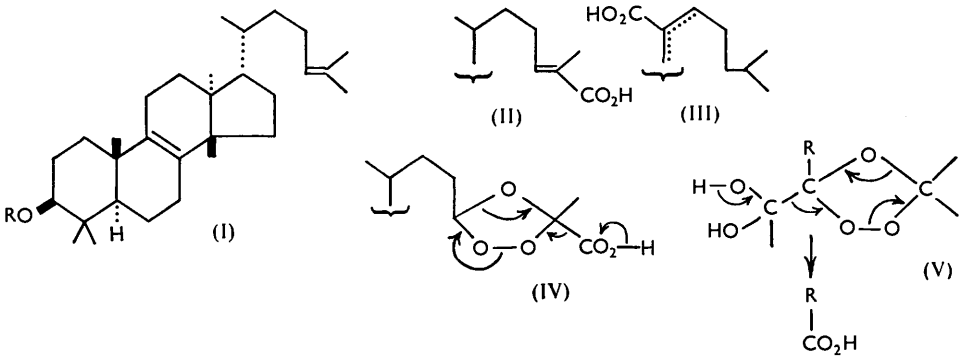
* Part XXI, *J.*, 1956, 788.

† Submitted in honour of the seventieth birthday of Sir Ian Heilbron, D.S.O., F.R.S.

[1] See Mills and Werner, *Nature*, 1952, **169**, 1064; cf. *idem*, *J.*, 1955, 3132; Mills, *Chem. and Ind.*, 1956, 189.

Gum mastic was examined by Tschirsh and Reutter [2] and by Casparis and Naef,[3] but it is extremely improbable that any of the compounds obtained by these workers was homogeneous. A crystalline unnamed acid constituent of the composition $C_{30}H_{46}O_3$ was reported recently by Mladenovic.[4] This acid may be identical with our masticadienonic acid described in the sequel, but the absence of the record by Mladenovic of any derivatives and of any physical constant except the m. p. prevents a definite decision.

After removal of polymeric hydrocarbon, gum mastic was separated into fractions which were severally neutral, acidic to sodium carbonate, and acidic to sodium hydroxide.



This paper is concerned with crystalline materials isolated from the first two of these fractions. It is hoped to report later on a crystalline acid that we have obtained from the third fraction.

Hydrolysis of the neutral fraction gave a product which was mainly neutral. Chromatography over alumina then afforded crystalline material which was identified as tirucallol (I; R = H).[5,6,7]

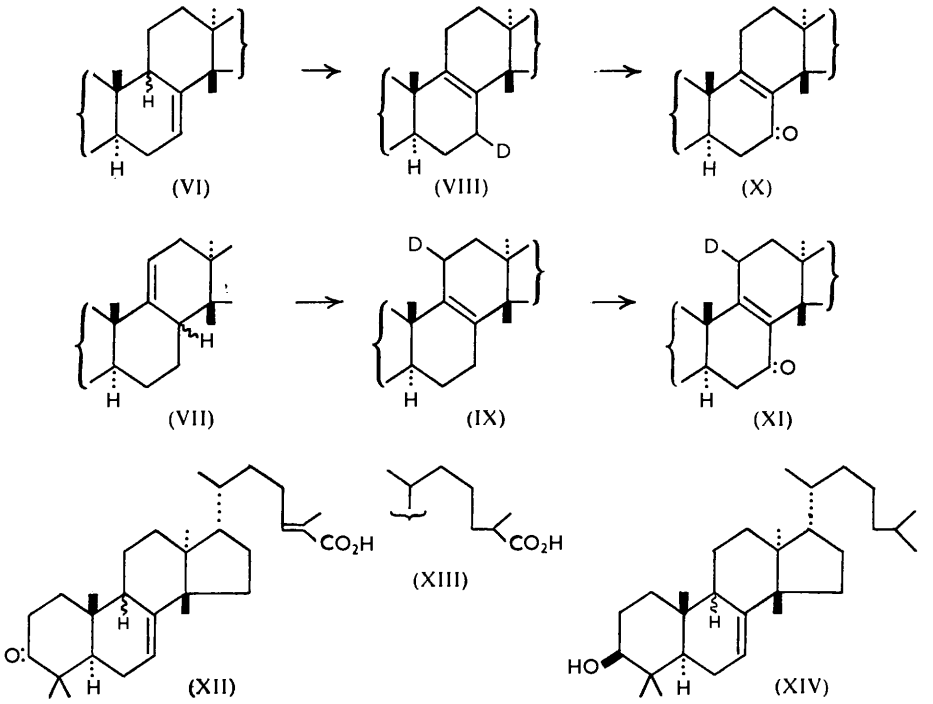
The acid fraction soluble in aqueous sodium carbonate was chromatographed over silica, to give a beautifully crystalline acid, $C_{30}H_{46}O_3$, which we designate masticadienonic acid. This was characterised as αβ-unsaturated by its ultraviolet absorption spectrum. The derived methyl ester had a similar spectrum and gave infrared bands at 1712 [superimposed ketone (see further below) and αβ-unsaturated ester] and 1650 cm.$^{-1}$ (ethylenic linkage of αβ-unsaturated ester grouping). The presence of a ketone grouping was shown by the preparation of a 2 : 4-dinitrophenylhydrazone and by reduction with sodium borohydride which afforded masticadienolic acid. Reduction with lithium aluminium hydride gave the expected masticadienediol.

The conjugated ethylenic linkage of masticadienonic acid was readily hydrogenated over palladium to furnish dihydromasticadienonic acid, further characterised as its methyl ester. The ultraviolet absorption spectra of these compounds showed the disappearance of the conjugated absorption but the retention of absorption equivalent to one non-conjugated ethylenic linkage (see further below). The methyl ester gave bands at 1738 (methoxycarbonyl) and 1710 cm.$^{-1}$ (six-ring ketone) in the infrared. Reduction of dihydromasticadienonic acid with sodium borohydride afforded dihydromasticadienolic acid, converted by conventional methods into the methyl ester and thence into the methyl ester acetate.

That masticadienonic acid contains two ethylenic linkages has already been implied (see above). The second, non-conjugated linkage gives a positive tetranitromethane test as shown by all compounds mentioned above. In specific confirmation of this feature

[2] Tschirsh and Reutter, *Arch. Pharm.*, 1904, **242**, 104.
[3] Casparis and Naef, *Pharm. Acta Helv.*, 1934, **9**, 19.
[4] Mladenovic, *Acta Pharm. Yugoslav.*, 1953, **3**, 1.
[5] Haines and Warren, *J.*, 1949, 2554; 1950, 1562.
[6] Barbour, Lourens, Watling, and Warren, *Chem. and Ind.*, 1955, 226; *J.*, 1955, 2194.
[7] Arigoni, Jeger, and Ruzicka, *Helv. Chim. Acta*, 1955, **38**, 222; Ménard, Wyler, Hiestand, Arigoni, Jeger, and Ruzicka, *ibid.*, p. 1517.

treatment of methyl dihydromasticadienolate acetate with ozone afforded a nicely crystalline epoxide (negative tetranitromethane test and no ultraviolet absorption) to which further reference is made below.



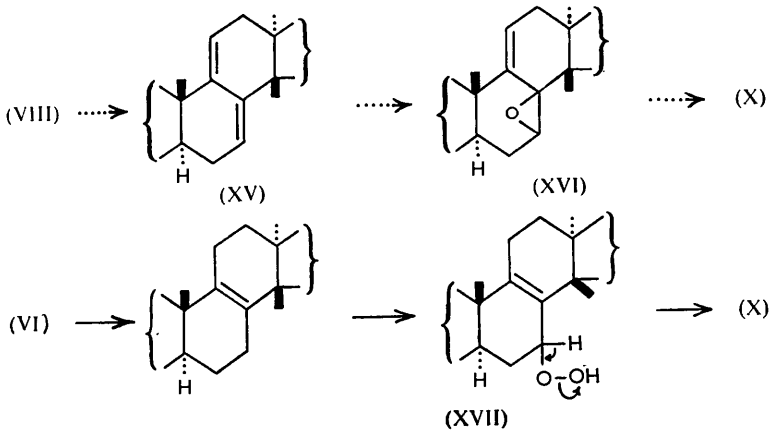
With the nature of the functional groups established it follows from the composition that masticadienonic acid must be tetracyclic. A possible relation to other tetracyclic triterpenoids was first inferred from the following experiments. Oxidation of methyl dihydromasticadienolate acetate with selenium dioxide afforded, with loss of two hydrogen atoms, a conjugated diene, the ultraviolet absorption spectrum of which ($\lambda_{max.}$ 240 mμ) showed that the diene system must be distributed over two rings. The same diene resulted from the epoxide mentioned above under mild acid conditions of dehydration. Attempted catalytic hydrogenation of methyl dihydromasticadienolate acetate in acetic acid solution over platinum gave an isomer, further characterised by hydrolysis to the parent hydroxy-acid. On oxidation with chromic acid the methyl ester acetate afforded a yellow diketo-derivative the ultraviolet absorption of which ($\lambda_{max.}$ 270 mμ) indicated the presence of the fully *transoid* ene-1 : 4-dione system so common in tetracyclic triterpenoids.[8] In agreement with the postulated ene-1 : 4-dione system reduction with zinc dust and acetic acid afforded a saturated diketone with no high-intensity ultraviolet absorption.

The main problem at this stage of the investigation was to convert the carboxyl group of masticadienonic acid, or a suitable derivative, into methyl. This was effected as follows. Reduction either of dihydromasticadienonic acid, or of its methyl ester, with lithium aluminium hydride gave dihydromasticadienediol. Attempted hydrogenation of this compound, after acetylation, gave on alkaline hydrolysis *iso*dihydromasticadienediol. Treatment of dihydromasticadienediol with toluene-*p*-sulphonyl chloride and pyridine afforded, according to the duration of the reaction, either a mono- or a di-toluene-*p*-sulphonate. Both of these compounds, or a mixture thereof, furnished on further reduction with lithium aluminium hydride a secondary alcohol, $C_{30}H_{52}O$, m. p. 108—110°, $[\alpha]_D$ −53°. Acetylation gave the acetate and this was rearranged smoothly over platinum under the

[8] For an excellent review see Halsall and Jones, *Fortschr. Chem. org. Naturstoffe*, 1955, **12**, 44.

conditions specified above to afford tirucallenol acetate (I; R = Ac). The identity was further confirmed by hydrolysis to tirucallenol (I; R = H). These experiments establish the nature of the carbon skeleton of masticadienonic acid and the position of the ketone grouping. The αβ-unsaturated acid function can only be placed as in (II) or (III). A decision in favour of (II) was secured by ozonolysis which gave one mol. of acetic acid. Such ozonolyses, employed recently in the work on tenulin,[9] are of the mechanistic types (electron release by O–H bond heterolysis) exemplified in (IV) and (V). These mechanisms also explain satisfactorily some recent results by Knights and Waight.[10]

There remains to be defined the exact position of the nuclear ethylenic linkage. This

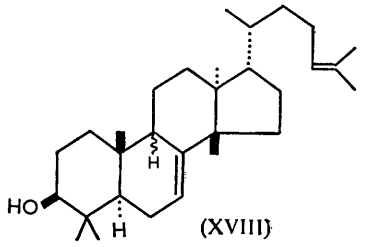


must be placed either at position 7 : 8 [as in (VI)] or at position 9 : 11 [as in (VII)]. A decision on this point was reached as follows. If the rearrangement of the nuclear ethylenic linkage were conducted over platinum in deuterium instead of hydrogen then one (or more) deuterium atoms would be introduced to give (VIII) or (IX). Now it has been shown [11] that treatment of euphenyl acetate (as I; R = Ac) [11,12,13] in ethyl acetate solution with ozone followed by a ferrous-ion wash affords a relatively good yield of 7-oxoeuphenyl acetate (as X). Now if this reaction were to be applied to the deuterated product (VIII) or (IX) one would obtain either (X), which would be free from deuterium, or (XI), which would retain its deuterium. In fact deuterogenation of methyl dihydromasticadienolate acetate over platinum in $CH_3 \cdot CO_2D$ gave a product containing just over one atom of deuterium.[14] This was oxidised by ozone to furnish the 7-ketone which contained no deuterium. The position of the ethylenic linkage is therefore established as in (VI) and complete structures can now be written for masticadienonic acid (XII), dihydromasticadienonic acid (XIII), and related compounds including the intermediate alcohol, m. p. 108—110° (see above) (XIV).

There is, however, a possible fallacy in the above proof of constitution which requires comment. If the ozonolysis of the deutero-compound (VIII) were to proceed through the corresponding diene (XV), its derived epoxide (XVI), and rearrangement,[15] then deuterium would be removed from both positions 7 and 11. Such a possibility was rejected by showing that methyl dehydrodihydromasticadienolate acetate (as XV), the preparation of which has been mentioned above, gave no 7-oxo-derivative on ozonolysis. Our interpretation of the mechanism of genesis of the ketone (X) is that it probably proceeds through the hydroperoxide (XVII) as indicated.

[9] Barton and de Mayo, *J.*, 1956, 142.
[10] Knights and Waight, *J.*, 1955, 2830.
[11] Barton, McGhie, Pradhan, and Knight, *J.*, 1955, 876.
[12] *Idem, Chem. and Ind.*, 1954, 1325.
[13] Arigoni, Viterbo, Dünnenberger, Jeger, and Ruzicka, *Helv. Chim. Acta*, 1954, **37**, 2306.
[14] For method of determination see Barton, Campos Neves, Cookson, and Eglinton, to be published.
[15] Cf., *inter al.*, Birchenough and McGhie, *J.*, 1950, 1249; Mijovic, Voser, Heusser, and Jeger, *Helv. Chim. Acta*, 1952, **35**, 964.

Recently the constitution and stereochemistry (XVIII) have been proposed for butyrospermol.[8,16,17] As would be expected there is a close relation between this compound and masticadienonic acid so far as the reactions of the nucleus are concerned. There is also the same negative molecular-rotation difference on oxidation to the ketone (see Table) and the same anomalous behaviour (see Experimental) of the latter towards the Zimmermann reagent.[18] In addition the various molecular-rotation correlations between the two series are in satisfactory agreement; in order to save space we do not present the data here. Rearrangement of the ethylenic linkage from 7 : 8 to 8 : 9 has already been noted on attempted catalytic hydrogenation in the butyrospermol series,[16] behaviour which is exactly as that recorded in the present paper.



(XVIII)

Alcohol	[M] Alcohol	[M] Ketone	Δ	Refs.
*cyclo*Artenol	+204°	+102°	−102°	*a*
*cyclo*Laudenol	+206	+ 83	−123	*b*
Butyrospermol	− 51	−170	−119	*c*
Masticadienolic acid	−201	−345	−144	*d*
Dihydromasticadienolic acid	−229	−365	−136	*d*
Methyl dihydromasticadienolate	−203	−353	−150	*d*

[a] Barton, *J.*, 1951, 1444. [b] Bentley, Henry, Irvine, Mukerji, and Spring, *J.*, 1955, 596. [c] Heilbron, Jones, and Robins, *J.*, 1949, 444. [d] This paper.

Finally we consider the stereochemistry of the terminal conjugated ethylenic linkage of masticadienonic acid. The evidence on this point is not rigid, but it seems to indicate that the configuration is the more stable *trans*, as in formula (XII). Thus masticadienolic acid was recovered unchanged after treatment with alkali under conditions considerably more drastic than those required [19] for a comparable *cis* ⟶ *trans* αβ-unsaturated acid isomerisation. Also the subtraction of the ultraviolet absorption curve of dihydromasticadienonic acid from that of masticadienonic acid (both determinations at the same concentration in acidified ethanol) gave a curve showing $\lambda_{max.}$ 218 mμ (ε 10,300) for the true absorption of the αβ-unsaturated acid function. This absorption is more intense than that recorded [20] for any *cis*-acid, but is fully comparable with that for a *trans*-configuration.

Experimental

Except as stated, rotations were determined in $CHCl_3$ solution. Ultraviolet absorption spectra were taken, unless specified to the contrary, in EtOH solution with the Unicam S.P. 500 Spectrophotometer. Infrared spectra were kindly determined by Dr. G. Eglinton and his associates on CCl_4 solutions. Silica gel for chromatography was obtained from Messrs. Hopkin and Williams Ltd. Light petroleum of b. p. 40—60° was used throughout, unless stated to the contrary.

Fractionation of Gum Mastic.—Finely powdered commercial gum mastic (480 g.) in ether (500 ml.) was diluted with methanol (3·5 l.) and left overnight. After decantation from the insoluble residue the solution was evaporated *in vacuo* and the residue again dissolved in ether (500 ml.) and diluted with methanol (3·5 l.). The operation was repeated (three times in all) until the gum was freely soluble in the ether–methanol mixture. The residue from this process, in ether (4 l.), was repeatedly extracted (*a*) with sodium carbonate solution (5%; 1 l.: emulsion), and (*b*) with 0·5N-sodium hydroxide (700 ml.). After acidification and re-extraction into ether there were obtained (*a*) sodium carbonate-soluble (and emulsion) acids (86 g.), (*b*) sodium hydroxide-soluble acids (24 g.), and (*c*) neutral residue (170 g.).

Examination of Neutral Fraction.—The neutral fraction (170 g.) in absolute ethanol (1 l.) was treated with sodium hydroxide (75 g.) in ethanol (1·5 l.) under reflux for 3 hr. Most of the

[16] Dawson, Halsall, Jones, Meakins, and Phillips, *Chem. and Ind.*, 1955, 918.
[17] Irvine, Lawrie, McNab, and Spring, *ibid.*, p. 626.
[18] Personal communication from Professor E. R. H. Jones, F.R.S., and Dr. T. G. Halsall.
[19] Myers, *J. Amer. Chem. Soc.*, 1951, **73**, 2100.
[20] Adams and van Duuren, *ibid.*, 1953, **75**, 4632.

solvent was removed *in vacuo* and the concentrated solution diluted with water and extracted with ether. This gave a hydrolysed neutral fraction (145 g.). A portion of this material (10 g.) was treated with pyridine (50 ml.) and acetic anhydride (25 ml.) at room temperature overnight, and the oily mixed acetates produced were chromatographed over alumina (300 g.) in benzene (10 ml.) and light petroleum (200 ml.). Elution with the same solvent mixture, increasing the proportion of benzene to 100%, gave 60 fractions of which fractions 4—10 gave a crystalline compound. For purification these fractions were hydrolysed with 5% ethanolic potassium hydroxide under reflux for 2 hr. The neutral product then crystallised well from methanol (300 mg.) and was identified as tirucallol by m. p. (135—136°), rotation {$[\alpha]_D$ +2° (*c* 1·10 in C_6H_6), −9° (*c* 1·06)}, and analysis (Found: C, 84·15; H, 11·9. Calc. for $C_{30}H_{50}O$: C, 84·45; H, 11·8%). Acetylation in the usual way gave (from methanol) tirucallyl acetate, identified by m. p. (159—161°), rotation {$[\alpha]_D$ −14° (*c* 1·24 in C_6H_6), −4° (*c* 1·16)}, and analysis (Found: C, 81·65; H, 11·0. Calc. for $C_{32}H_{52}O_2$: C, 82·0; H, 11·2%). Benzoylation in the usual way afforded (from chloroform–methanol) tirucallyl benzoate, identified by m. p. (145—147°) and rotation {$[\alpha]_D$ +32° (*c* 1·11)}. For these compounds Haines and Warren [5] recorded the constants: m. p. 133—135°, $[\alpha]_D$ +5°, m. p. 164°, $[\alpha]_D$ −17°, m. p. 149—151°, $[\alpha]_D$ +11°, for the alcohol, acetate, and benzoate respectively (all rotations in C_6H_6).

Hydrogenation of the tirucallyl acetate in acetic acid solution over platinum gave tirucallenyl acetate, identified by m. p., mixed m. p., rotation {$[\alpha]_D$ −12° (*c* 1·04 in C_6H_6), −1° (*c* 1·35)}, and analysis (Found: C, 81·45; H, 11·45. Calc. for $C_{32}H_{54}O_2$: C, 81·65; H, 11·55%). Alkaline hydrolysis afforded tirucallenol, identified by m. p., mixed m. p., and rotation {$[\alpha]_D$ +3° (*c* 1·05 in C_6H_6), −9° (*c* 1·00)}.

Masticadienonic Acid.—The acid fraction (*a*) (see above) (10 g.) in 1 : 1 benzene–light petroleum (300 ml.) was chromatographed over silica gel (400 g.) (20 fractions in all). Elution with benzene and with 1 : 3 ether–benzene gave *masticadienonic acid* (1·4 g.), m. p. 178° (from ether–light petroleum), $[\alpha]_D$ −76° (*c* 1·35), $\lambda_{max.}$ 214 mμ (ε 12,500) [Found: C, 79·05; H, 10·0; equiv. (potentiometric), 451, 453. $C_{30}H_{46}O_3$ requires C, 79·25; H, 10·2%; equiv., 455]. The acid gave a positive tetranitromethane test, but a very weak Zimmermann colour.

Treatment of masticadienonic acid (108 mg.) in methylene dichloride (20 ml.) at −25° with ozone (excess), addition of water, and separation of the aqueous layer gave a solution which on distillation afforded 0·82 mol. of volatile acid. This was converted into the *p*-bromophenacyl ester and identified as the acetic acid derivative by m. p., mixed m. p. and ultraviolet absorption spectrum ($\lambda_{max.}$ 257 mμ; ε 18,000; identical with that of an authentic specimen).

Treatment of masticadienonic acid with diazomethane in the usual way furnished *methyl masticadienonate*, m. p. (from methanol) 125°, $[\alpha]_D$ −77° (*c* 0·64), $\lambda_{max.}$ 214 mμ (ε 12,700) (Found: C, 79·75; H, 10·0. $C_{31}H_{48}O_3$ requires C, 79·45; H, 10·3%).

Masticadienonic acid gave a 2 : 4-*dinitrophenylhydrazone*, m. p. 245° (from chloroform–ethanol), $\lambda_{max.}$ 370 mμ (ε 24,400 in $CHCl_3$) (Found: C, 68·1; H, 7·6; N, 9·15. $C_{36}H_{50}O_6N_4$ requires C, 68·1; H, 7·95; N, 8·85%).

Reduction of masticadienonic acid (135 mg.) in methanol (30 ml.) with sodium borohydride (90 mg.) in water (1 ml) overnight at room temperature gave *masticadienolic acid*, m. p. 200—201° (from methanol), $[\alpha]_D$ −44° (*c* 1·12), $\lambda_{max.}$ 212 mμ (ε 12,100) (Found: C, 78·7; H, 10·35. $C_{30}H_{48}O_3$ requires C, 78·9; H, 10·6%).

Reduction of masticadienonic acid (416 mg.) in dry ether (50 ml.) with lithium aluminium hydride (900 mg.) in the same solvent (100 ml.) under reflux for 3 hr. afforded *masticadienediol*, m. p. 186—187° (from benzene) $[\alpha]_D$ −51° (*c* 1·46), $\lambda_{max.}$ 205 mμ (ε 9700) (Found: C, 81·7; H, 11·05. $C_{30}H_{50}O_2$ requires C, 81·4; H, 11·4%).

Masticadienolic acid (140 mg.) was refluxed with ethanolic potassium hydroxide [23] (28%; 2 ml.) for 5 hr. and also for 11 hr. In both cases starting material (100 mg.) was recovered and identified by m. p., mixed m. p., and rotation. Chromatography over silica gel did not disclose a second acid.

Dihydromasticadienonic Acid.—Masticadienonic acid (169 mg.) in ethyl acetate (40 ml.) was hydrogenated over palladised charcoal (10%; 150 mg.) (uptake of hydrogen, 1 mol.), to give *dihydromasticadienonic acid*, m. p. 156° (from aqueous methanol), $[\alpha]_D$ −80° (*c* 1·13), $\lambda_{max.}$ 207, 290 mμ (ε 4700, 40 respectively) (Found: C, 79·1; H, 10·8. $C_{30}H_{48}O_3$ requires C, 78·9; H, 10·6%). Treatment with ethereal diazomethane in the usual way gave *methyl dihydromasticadienonate*, m. p. 90° (after chromatography over alumina, elution with 1 : 2 benzene–light petroleum and crystallisation from aqueous methanol), $[\alpha]_D$ −75° (*c* 1·71) (Found: C, 79·1; H, 10·65. $C_{31}H_{50}O_3$ requires C, 79·1; H, 10·7%).

Dihydromasticadienolic Acid.—Dihydromasticadienonic acid (398 mg.) in methanol (40 ml.)

was treated overnight at room temperature with sodium borohydride (240 mg.) in water (2 ml.). Crystallisation of the product from methanol gave *dihydromasticadienolic acid*, m. p. 208° (from methanol), $[\alpha]_D$ −50° (*c* 1·23) (Found : C, 78·55; H, 10·8. $C_{30}H_{50}O_3$ requires C, 78·55; H, 11·0%). Treatment with diazomethane in the usual way afforded *methyl dihydromasticadienolate*, m. p. 117—118° (from aqueous methanol), $[\alpha]_D$ −43° (*c* 1·01) (Found : C, 78·75; H, 10·85. $C_{31}H_{52}O_3$ requires C, 78·75; H, 11·1%). Acetylation with pyridine–acetic anhydride overnight at room temperature gave *methyl dihydromasticadienolate acetate*, m. p. 92—93° (from aqueous methanol after filtration over alumina in 1 : 4 benzene–light petroleum), $[\alpha]_D$ −30° (*c* 1·01), $\lambda_{max.}$ 205 mμ (ε 5800) (Found : C, 76·4; H, 10·4. $C_{33}H_{54}O_4$ requires C, 77·0; H, 10·55%).

This methyl ester acetate (77 mg.) in ethanol (10 ml.) was refluxed with selenium dioxide (200 mg.), and the development of the ultraviolet chromophore determined (3 hr., ε 2100; 6 hr., ε 3000; 18 hr., ε 10,000; all readings at $\lambda_{max.}$ 240 mμ). The product was chromatographed over alumina in benzene–light petroleum mixtures, to give *methyl dehydrodihydromasticadienolate acetate*, m. p. 94—95° (from aqueous methanol), $[\alpha]_D$ −133° (*c* 1·21), $\lambda_{max.}$ 240 mμ (ε 15,800) (Found : C, 74·9; H, 9·7. $C_{33}H_{52}O_4,H_2O$ requires C, 74·65; H, 10·25%).

Treatment of methyl dihydromasticadienolate acetate (200 mg.) in ethyl acetate (10 ml.) with ozone at −25°, until the tetranitromethane test was negative (30 min.), gave *methyl dihydromasticadienolate acetate epoxide* (147 mg.), m. p. 152—154° (from methanol), $[\alpha]_D$ −57° (*c* 1·00) (Found : C, 74·7; H, 10·05. $C_{33}H_{54}O_5$ requires C, 74·65; H, 10·25%). This epoxide (100 mg.) in chloroform (2 ml.) was treated for 5 min. with dry hydrogen chloride and left at room temperature for 2 hr. The product was chromatographed over alumina (6 g.) in 1 : 3 benzene–light petroleum to give (five fractions : m. p., mixed m. p., and ultraviolet absorption spectrum) the dehydro-ester referred to above.

Methyl iso*Dihydromasticadienolate Acetate and Derivatives.*—Methyl dihydromasticadienolate acetate (80 mg.) in " AnalaR " acetic acid (5 ml.) was hydrogenated over platinum for 2 hr. at room temperature. Crystallisation of the product from aqueous methanol furnished *methyl* iso*dihydromasticadienolate acetate*, m. p. 97—98°, $[\alpha]_D$ −5° (*c* 1·10), $\lambda_{max.}$ 205 mμ (ε 5200) (Found : C, 76·9; H, 10·65%).

This methyl ester acetate (200 mg.) in " AnalaR " acetic acid (10 ml.) was treated at room temperature with chromium trioxide in the same solvent (0·5N; 10 ml.) for 3 days. The product was chromatographed over alumina, elution with benzene–light petroleum mixtures affording *methyl* iso*dihydro*-7 : 11-*dioxomasticadienolate acetate*, m. p. 115—116° (from aqueous methanol), $[\alpha]_D$ −13° (*c* 1·06), $\lambda_{max.}$ 270 mμ (ε 8000) (Found : C, 73·25; H, 9·15. $C_{33}H_{50}O_6$ requires C, 73·05; H, 9·6%). Under the same oxidation conditions methyl dihydromasticadienolate acetate gave no ultraviolet chromophore.

The 7 : 11-diketone (50 mg.) in " AnalaR " acetic acid (2 ml.) was heated on the steam-bath with excess of zinc dust for 1 hr. Chromatography of the product over alumina in benzene–light petroleum mixtures gave the saturated 7 : 11-*diketone*, m. p. 177—179° (from methanol), $[\alpha]_D$ −117° (*c* 0·87), ε <200 at 220—320 mμ (Found : C, 72·4; H, 9·3. $C_{33}H_{52}O_6$ requires C, 72·75; H, 9·3%).

Hydrolysis of methyl *iso*dihydromasticadienolate acetate (100 mg.) with ethanolic potassium hydroxide (3%; 10 ml.) for 2 hr. under reflux gave iso*dihydromasticadienolic acid*, m. p. 210—212° (from aqueous methanol), $[\alpha]_D$ −6° (*c* 1·40) (Found : C, 78·7; H, 11·35. $C_{30}H_{50}O_3$ requires C, 78·55; H, 11·0%).

Dihydromasticadienediol and its Derivatives.—Methyl dihydromasticadienolate (650 mg.) in dry ether (150 ml.) was reduced with lithium aluminium hydride (380 mg.) in the same solvent under reflux for 2 hr. Crystallisation of the product from methanol furnished *dihydromasticadienediol*, m. p. 165—166°, $[\alpha]_D$ −55° (*c* 1·65) (Found : C, 81·4; H, 12·4. $C_{30}H_{52}O_2$ requires C, 81·0; H, 11·8%). This diol can also be obtained conveniently by the analogous reduction of dihydromasticadienonic acid.

Dihydromasticadienediol (178 mg.) in pyridine (3 ml.) was treated with toluene-*p*-sulphonyl chloride (611 mg.) (initial cooling) for 30 min. at room temperature. The product was chromatographed over alumina (6 g.) in 1 : 1 benzene–light petroleum. Elution with this solvent (four fractions) gave an oil, the absorption spectrum of which ($\lambda_{max.}$ 225 mμ; ε 29,000) showed that it was the ditoluene-*p*-sulphonate. Elution with benzene (14 fractions) gave a crystalline product, m. p. approx. 100—104° (from aqueous methanol), $[\alpha]_D$ −35° (*c* 1·05), the absorption spectrum of which ($\lambda_{max.}$ 225 mμ; ε 14,300) indicated that it was the *monotoluene*-p-*sulphonate* (Found : C, 74·3; H, 9·35; S, 5·35. $C_{37}H_{58}O_4S$ requires C, 74·2; H, 9·75; S, 5·35%). Elution with 1 : 9 ether–benzene (three fractions) gave back unchanged starting material (m. p. and

mixed m. p.). Increasing the reaction time increased the ratio of di- to mono-toluene-*p*-sulphonate; after 4 hr. only the oily ditoluene-*p*-sulphonate could be isolated. Reduction of the mono- or of the di-toluene-*p*-sulphonate, or of the crude toluene-*p*-sulphonation mixture, with lithium aluminium hydride gave in each case the same result. The following experiment is exemplary. The monotoluene-*p*-sulphonate (91 mg.) in dry ether (25 ml.) was refluxed with lithium aluminium hydride (800 mg.) in the same solvent (25 ml.) for 36 hr. The product in benzene was chromatographed over alumina (3 g.). Elution with 1 : 19 ether–benzene (seven fractions) furnished *tirucall-7-enol*, m. p. 108—110° (from methanol), $[\alpha]_D$ −53° (*c* 1·05), $\lambda_{max.}$ 207 mμ (ε 4900) (Found: C, 84·05; H, 12·4. $C_{30}H_{52}O$ requires C, 84·05; H, 12·25%). Treatment with pyridine–acetic anhydride overnight at room temperature gave *tirucall-7-enyl acetate*, m. p. 127—128° (from chloroform–methanol), $[\alpha]_D$ −30° (*c* 1·46) (Found: C, 81·7; H, 11·85. $C_{32}H_{54}O_2$ requires C, 81·65; H, 11·55%). This acetate (160 mg.) in " AnalaR " acetic acid (26 ml.) was hydrogenated over platinum for 2 hr. The product, after crystallisation from chloroform–methanol, was identified as tirucallenyl acetate by m. p., mixed m. p., rotation {$[\alpha]_D$ −15° (*c* 0·98 in C_6H_6), −6° (*c* 1·08)}, and analysis (Found: C, 81·45; H, 11·3%). Alkaline hydrolysis (5% ethanolic potassium hydroxide on the steam-bath for 2 hr.) gave (from methanol) tirucallenol, identified by m. p., mixed m. p., rotation {$[\alpha]_D$ +2° (*c* 0·93 in C_6H_6), −11° (*c* 1·03)}, absorption spectrum (λ_{max} 205 mμ; ε 6700), and analysis (Found: C, 83·65; H, 12·2. Calc. for $C_{30}H_{52}O$: C, 84·05; H, 12·25%).

Masticadienediol (94 mg.) was acetylated with pyridine–acetic anhydride overnight at room temperature. The diacetate, which did not crystallise, was hydrogenated in " AnalaR " acetic acid (30 ml.) over platinum oxide for 14 hr. The product was hydrolysed with 5% ethanolic potassium hydroxide under reflux for 2 hr., to give iso*dihydromasticadienediol* (56 mg.), m. p. 157—158° (from methanol), $[\alpha]_D$ −5° (*c* 1·02) (Found: C, 80·9; H, 11·6. $C_{30}H_{52}O_2$ requires C, 81·0; H, 11·8%).

Methyl iso*Dihydro-7-oxomasticadienolate Acetate.*—Methyl *iso*dihydromasticadienolate acetate (250 mg.) in ethyl acetate (10 ml.) was ozonised at −25° until a portion of the solution gave a negative test with tetranitromethane. The solution was washed with cold aqueous ferrous sulphate (5%), and the ethyl acetate removed *in vacuo*. The product was chromatographed over alumina (7·0 g.) in 1 : 3 light petroleum–benzene. Elution with benzene (four fractions) gave *methyl* iso*dihydro-7-oxomasticadienolate acetate* (20 mg.), m. p. 138—140° (from aqueous methanol), $[\alpha]_D$ −15° (*c* 1·35), $\lambda_{max.}$ 255 mμ (ε 10,000) (Found: C, 75·25; H, 9·75. $C_{33}H_{52}O_5$ requires C, 74·95; H, 9·9%). Methyl dehydrodihydromasticadienolate acetate (see above), ozonised under the same conditions, showed no sign of any enone chromophore in the ultra-violet spectrum and gave no tractable product on chromatography.

Rearrangement of Methyl Dihydromasticadienolate Acetate with Deuterium.—[*carboxy*-^{2}H]-Acetic acid was prepared by treating " AnalaR " acetic anhydride with the theoretical amount of deuterium oxide. The acid was purified by repeated fractional distillation, and its purity checked by titration. For the rearrangement standard conditions, the adequacy of which was checked by using ordinary hydrogen, were employed as follows. Methyl dihydromasticadienolate acetate (200 mg.) in deuteroacetic acid (17 ml.) was shaken for 3 hr. over platinum oxide (100 mg.) under 1 atm. of deuterium. The latter was prepared by the addition of deuterium oxide (6 ml.; mixed with dioxan, 5 ml.) to metallic sodium (3·0 g.; small pieces) suspended in dioxan (7 ml.). The dioxan was purified twice before use. The apparatus was of the vacuum type and the deuterium came into contact only with mercury. The product of rearrangement had the same physical constants as those recorded above for methyl *iso*dihydromasticadienolate acetate. In CCl_4 the compound showed an infrared band at 2100 cm.$^{-1}$ indicative of *C*-deuterium and of an intensity (band area; calibrated against 27-deutero-α-amyrin acetate of known deuterium content) equivalent to 1·13 *C*-D. This product was ozonised as described above, giving the 7-oxo-derivative, m. p. and mixed m. p. 137—140°, $[\alpha]_D$ −14° (*c* 0·92), $\lambda_{max.}$ 255 mμ (ε 10,000). Infrared examination as above showed 0·0 *C*-D.

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