18-in. spinning-band column, collecting the fraction (9.5 g) of bp 140–170°. Vpc analysis (on a column of DC 710 supported on Chromosorb W, 20 mesh, at 165° with a helium flow rate of 75 ml/min) showed two peaks with retention times of 29 and 32 min, in the ratio 2:5. Samples of both substances were collected by repeated injection on the same column.

The faster moving component was identified as **methyl-*trans*-2-methylcyclopentanecarboxylate**, $[\alpha]^{25}D$ −57.5° (c 0.2, carbon tetrachloride). It was converted to the amide by bubbling dry ammonia through a solution of the ester (120 mg) in 5 ml of methanol for 30 min, then keeping the solution sealed at room temperature for 3 days. The solvent was removed in a stream of dry nitrogen and the residue was crystallized from benzene–petroleum ether (bp 30–60°). The amide (XVII) had mp 149.0–149.5°, $[\alpha]^{26}D$ −40.2° (c 0.0076, water).[36] Hooper, *et al.*,[5] reported mp 152–153.5°, $[\alpha]^{20}D$ −13.7° (c 1, water), for the amide prepared from dihydrosarkomycin. The infrared and nmr spectra of XVII were identical with those of an authentic sample of the racemic amide,[37] mp 149–150°.

The second substance eluted from the vpc column was an isomeric ester [mol wt 142 (mass spectrum), $[\alpha]^{25}D$ −6.8° (c 0.2, carbon tetrachloride)] which was converted in the same manner to the amide [mp 148.5–149.5°, $[\alpha]^{25}D$ −32.2° (c 0.01, water)].[36] This is tentatively regarded as one of the stereoisomers of 3-methylcyclopentanecarboxamide; the racemic amide (configuration unknown) melted[37a] at 147–148°.

Registry No.—(−)-I, 13012-37-8; (+)-III, 13012-38-9; (+)-III 2,4-dinitrophenylhydrazone, 13012-39-0; V, 13052-48-7; V *p*-nitrobenzoate, 13012-40-3; (+)-X, 7712-68-7; (−)-XI, 13012-42-5; (−)-XII, 13012-43-6; (−)-XIII, 13012-44-7; (−)-XIII bis-*p*-nitrobenzoate, 13012-45-8; (−)-XIV, 13012-46-9; (−)-XV, 13012-47-0; (−)-XV bis-*p*-nitrobenzoate, 13012-48-1; (−)-XVII, 13012-49-2; methyl *trans*-2-methylcyclopentanecarboxylate, 13012-50-5; 3-methylcyclopentanecarboxamide, 13012-51-6.

Acknowledgment.—The authors express their thanks to Mr. Norman Gilman for obtaining the nmr spectra.

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[36] This rotation was measured on a Cary spectropolarimeter; we thank Mr. Grant Krow for the measurement.

[37] (a) W. O. Ney, W. W. Crouch, C. E. Rannefeld, and H. L. Lochte, *J. Am. Chem. Soc.*, **65**, 770 (1943); (b) H. Pines and N. E. Hoffman, *ibid.*, **76**, 4417 (1954); (c) M. Julia and F. Le Goffic, *Bull. Soc. Chim. France*, 1550 (1965). We are grateful to Professor M. Julia and Mr. M. Maumy for sending us a sample of racemic *trans*-2-methylcyclopentanecarboxylic acid.

Synthetic Experiments in the Eudalene Group of Bicyclic Sesquiterpenes. III.[1] Total Synthesis of (+)-α- and (+)-β-Eudesmols

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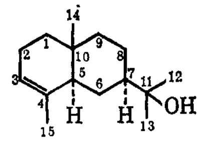
The total syntheses of (+)-α-eudesmol and (+)-β-eudesmol are described.

The natural product known as eudesmol has been recognized for many years to be a mixture of two and sometimes three isomeric alcohols, depending upon the source of the material.[6] These alcohols are the double-bond isomers α-, β-, and γ-eudesmols, proved to have structures **1**, **2**, and **3**, respectively. The constitution **3** assigned to γ-eudesmol is based on its chemical transformations,[7] and it has been confirmed by total synthesis[8] that **3** represents the structure and absolute configuration of (+)-γ-eudesmol. The structure **2** for the β isomer is also based on its chemical behavior,[6] and stereochemical studies[9] have shown that **2** represents (+)-β-eudesmol; a recent stereoselective total synthesis of (±)-β-eudesmol has provided confirmation.[10] The structure of α-eudesmol (**1**) is based on its chemical transformations.[6] In this paper we describe stereoselective total syntheses of (+)-α-eudesmol and (+)-β-eudesmol, which confirm structures and absolute configurations **1** and **2**, respectively, for these alcohols.[11]



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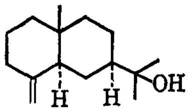

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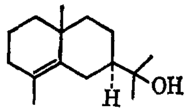

3

Synthesis of (+)-β-Eudesmol

The starting point in our first approach to (+)-β-eudesmol was (+)-15-nor-α-cyperone[12] (**4**) obtainable by a Robinson–Mannich annelation reaction between (+)-dihydrocarvone and 1-diethylaminobutan-3-one methiodide.[1] Compound **4** was a minor product of the annelation reaction; it was isolated through its semicarbazone by a rather tedious procedure, and in very poor yield.[1] Nevertheless, sufficient material was obtained to make a synthetic sequence starting from it possible. The absolute configuration of **4** was settled by the observation that its ORD curve is almost superimposable on that of (+)-α-cyperone, of proven absolute configuration (**5**).[13] Treatment of **4**

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[1] Part II: D. C. Humber and A. R. Pinder, *J. Org. Chem.*, **31**, 4188 (1966).

[2] Abstracted in part from theses presented by D. C. H. and R. A. W. in partial fulfilment of the requirements for the degree of Doctor of Philosophy in the University of Wales.

[3] Glaxo Research Ltd., Greenford, Middlesex, England.

[4] To whom enquiries should be addressed at Clemson University.

[5] Department of Chemistry, North Staffordshire College of Technology, Stoke-on-Trent, England.

[6] For a review of eudesmol chemistry, see D. H. R. Barton, in "Chemistry of Carbon Compounds," Vol. IIB, E. H. Rodd, Ed., Elsevier Publishing Co., Amsterdam, 1953, p 664.

[7] (a) F. J. McQuillin and J. D. Parrack, *J. Chem. Soc.*, 2973 (1956); (b) R. B. Bates and E. K. Hendrickson, *Chem. Ind.* (London), 1759 (1962).

[8] A. R. Pinder and R. A. Williams, *J. Chem. Soc.*, 2773 (1963).

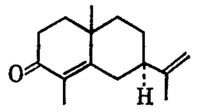
[9] (a) A. J. Birch and K. M. C. Mostyn, *Australian J. Chem.*, **7**, 301 (1954); (b) B. Riniker, J. Kalvoda, D. Arigoni, A. Fürst, O. Jeger, A. M. Gold, and R. B. Woodward, *J. Am. Chem. Soc.*, **76**, 313 (1954).

[10] J. A. Marshall and M. T. Pike, *Tetrahedron Letters*, 3107 (1965); J. A. Marshall, M. T. Pike, and R. D. Carroll, *J. Org. Chem.*, **31**, 2933 (1966).

[11] For preliminary accounts, see (a) R. P. Houghton, D. C. Humber, and A. R. Pinder, *Tetrahedron Letters*, 353 (1966); (b) D. C. Humber and A. R. Pinder, *ibid.*, 4985 (1966).

[12] We are using the numbering for the eudesmane ring system proposed by W. Cocker and T. B. H. McMurry, *Tetrahedron*, **8**, 181 (1960), as depicted in formula **1**. In our earlier paper[1] we have described compound **4** as (+)-4-nor-α-cyperone; we now feel it is better designated (+)-15-nor-α-cyperone.

[13] R. Howe and F. J. McQuillin, *J. Chem. Soc.*, 2423 (1955).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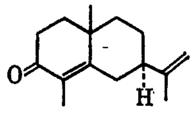
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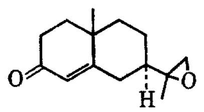
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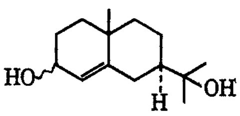
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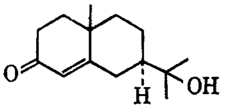
with perbenzoic acid afforded the 11,12-epoxide 6, which was reduced by lithium aluminum hydride to the diol 3-hydroxy-15-nor-γ-eudesmol (7) as a mixture of C_8 epimerides. Oxidation with activated manganese dioxide[14] gave (+)-15-norcarissone 8, which was converted to its ethylene dithioketal 9 on treatment with ethanedithiol and boron trifluoride etherate. Attempts to desulfurize the dithioketal 9 to 15-nor-γ-eudesmol (10) were, at this juncture, unsuccessful, the product containing appreciable amounts of the corresponding fully saturated alcohol in each experiment. Satisfactory separation of these did not prove practicable. However, satisfactory conditions for this desulfurization were eventually discovered (see below).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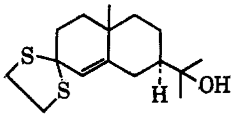
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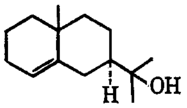
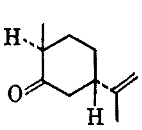

10

Attention was next turned to the possible use of (−)-dihydrocarvone, of established stereochemistry[15] 11, as starting point. A Robinson–Mannich reaction between the ketone and nascent methyl vinyl ketone (from 4-diethylaminobutan-3-one methiodide and methylsulfinyl carbanion[16] in dimethyl sulfoxide) afforded the *cis*-ketol 12. The possibility that the product might have the bridged structure[17] 13 was ruled out by the fact that its nmr spectrum showed only two singlet methyl proton signals, at 1.18 and 1.68 ppm (TMS = 0). The *cis* stereochemistry at the ring junction was settled by a knowledge of the steric course[18] of the annelation reaction, and by the fact that the ORD curve[19] of the ketol 12 bore a mirror-image relationship to that of 14, described earlier.[1] Further, the ORD curve of 12 is quite unlike that of coprostan-3-one, in agreement with the expectation that 12 has nonsteroidal *cis*-fused rings, as in 15 (strong positive Cotton effect).[20] The observed chemical shift (1.18 ppm) of the angular methyl group in 12 is in agreement with this assignment of conformation.[18,21]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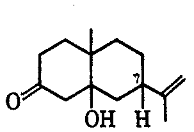
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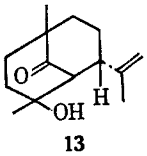
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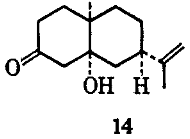
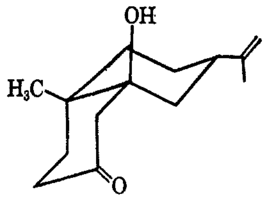

14

Accompanying the ketol 12 as minor products were the aldol-type compound[16b] 16, and the octalones 17 and 18, 16 being separable from the ketone mixture by chromatography. The aldol is formulated as 16 because its physical and chemical properties are identical (except for its specific rotation, which is opposite in sign) with those of the enantiomorph described earlier.[1] The ketones 17 and 18 were present in the ratio 1:2; a partial separation, leading to pure 18, was possible through the mixed semicarbazones, but this compound was more conveniently obtained by acid-catalyzed dehydration of ketol 12.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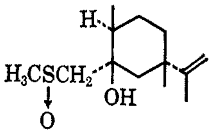
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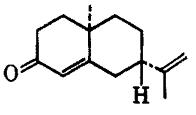
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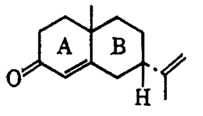
18

Ozonolysis of octalone 18 afforded the diketone 19, together with the epoxide 20, the products being separable by preparative thin layer chromatography. The $4\alpha,5\alpha$ configuration 20 for the epoxide is based on its correspondence in physical and chemical properties (with equal, but opposite, specific rotation) with the enantiomorphous product.[1] The formation of 20 could be suppressed by effecting the ozonolysis in the presence of pyridine.[22] Similarly, the assignment of the 7α configuration for the acetyl group in 19 is justified by the correspondence in spectral and optical rotatory dispersion properties between 19 and its enantiomer, described in our earlier paper.[1] Treatment of 19 with acid, as anticipated, induced epimerization at position 7, with formation of the 7β-acetyloctalone 21. The driving force behind this facile inversion is presumably the fact that in 18, and therefore in its ozonoly-

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(14) O. Mancera, G. Rosenkranz, and F. Sondheimer, *J. Chem. Soc.*, 2189 (1953).

(15) A. J. Birch, *Ann. Rept. Chem. Soc.*, **47**, 192 (1950), and references cited therein.

(16) (a) E. J. Corey and M. Chaykovsky, *J. Am. Chem. Soc.*, **84**, 866 (1962); (b) *ibid.*, **87**, 1345 (1965); (c) G. G. Price and M. C. Whiting, *Chem. Ind.* (London), 775 (1963).

(17) *Cf.* W. S. Johnson, J. J. Korst, R. A. Clement, and J. Dutta, *J. Am. Chem. Soc.*, **82**, 614 (1960).

(18) F. J. McQuillin, *J. Chem. Soc.*, 528 (1955); T. A. Spencer, K. K. Schmiegel, and K. L. Williamson, *J. Am. Chem. Soc.*, **85**, 3785 (1963); J. A. Marshall and W. I. Fanta, *J. Org. Chem.*, **29**, 2501 (1964); T. A. Spencer, H. S. Neel, D. C. Ward, and K. L. Williamson, *ibid.*, **31**, 434 (1966); K. L. Williamson, L. R. Sloan, T. Howell, and T. A. Spencer, *ibid.*, **31**, 436 (1966).

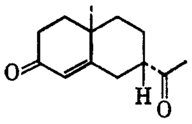
(19) We are greatly indebted to Professor W. Klyne, Dr. P. M. Scopes, and Dr. S. Wallis (Westfield College, University of London) for ORD measurements and discussions.

(20) *Cf.* R. Howe and F. J. McQuillin, *J. Chem. Soc.*, 1194 (1958); T. G. Halsall, D. W. Theobald, and K. B. Walshaw, *ibid.*, 1029 (1964); C. Djerassi, "Optical Rotatory Dispersion," McGraw-Hill Book Co., Inc., New York, N. Y., 1960, p 185.

(21) W. G. Dauben, R. M. Coates, N. D. Vietmeyer, L. J. Durham, and C. Djerassi, *Experientia*, **21**, 565 (1965).

(22) *Cf.* G. Slomp and J. L. Johnson, *J. Am. Chem. Soc.*, **80**, 915 (1958).

sis product **19**, ring B is a boat, to allow the C$_7$ substituent to be equatorial. The ORD curve of **18** is very similar to that of epi-α-cyperone, **22**, and of 8-isotestosterone; in both these compounds there are convincing reasons for believing that ring B is severely distorted so as to be roughly boat shaped.[23] Inversion at C$_7$ in **19** permits ring B to assume the thermodynamically more stable chair conformation, with attendant equatorial 7β-acetyl group, as in **21**.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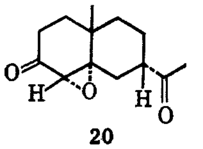
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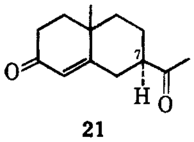
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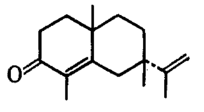
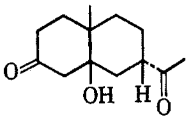

22

The diketone **21** was also obtainable, in better yield, by ozonolysis of the ketol **12**, to the diketo alcohol **23**, followed by acid dehydration, with concomitant epimerization. The ORD curve of **23** resembled closely that of **12**, indicating that the ozonolysis product was similar in conformation to **12**.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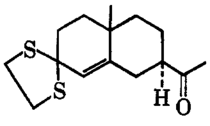
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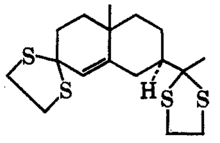
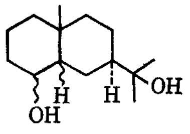

25

Condensation of diketone **21** with ethanedithiol (1 mole) resulted mainly in a selective attack[24] on the conjugated carbonyl group, with formation of **24**, accompanied by a small amount of the bis(ethylene dithioketal) **25**. The two were separated by fractional crystallization, and **24**, identified by its infrared spectrum and analysis, was treated with methylmagnesium iodide, to give the alcohol **9**. Desulfurization of **9** with sodium and liquid ammonia[25] furnished 15-nor-γ-eudesmol (**10**); the use of a partially poisoned Raney nickel catalyst achieved substantially the same result. The ORD curve of this product was almost identical with that of γ-eudesmol[8] (**3**). Hydroboration of 15-nor-γ-eudesmol gave, after oxidation with hydrogen peroxide, a mixture of epimeric alcohols **26**; this, on oxidation with Jones reagent[26] afforded a mixture of epimeric 1-decalones, which on exposure to basic alumina[27] was homogenized to the *trans*-1-decalone **27**. The latter compound proved to be identical in every respect with the crystalline ketone obtained by the ozonolysis of commercial eudesmol.[9a,28] Ketone **27** had an ORD curve closely similar to that of cholestan-4-one,[29] confirming the assigned stereochemistry. Finally, a Wittig reaction between **27** and methylenetriphenylphosphorane gave (+)-β-eudesmol (**2**), purified by preparative thin layer chromatography and vacuum sublimation, and identical in all respects with natural (+)-β-eudesmol, separated from commercial eudesmol.[30]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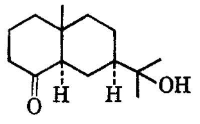
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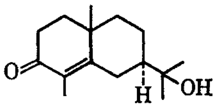
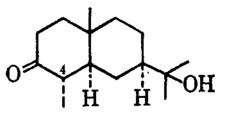

28

This synthesis is also a synthesis of cryptomeridiol[31] and neointermedeol,[32] both of which have been synthesized from (+)-β-eudesmol.

Synthesis of (+)-α-Eudesmol

The starting point in this synthesis was (+)-carissone (**28**), the structure[33] and absolute configuration[8,34] of which are firmly established. Reduction with lithium in liquid ammonia[35] afforded a product consisting in the main of the expected *trans*-dihydrocarissone (**29**) accompanied by a small amount of the corresponding diol **30**. The crude product was treated with Jones reagent,[26] to give a homogeneous ketonic product **29**, in which we assign the more stable α configuration (equatorial) to the C$_4$-methyl group. The dihydro ketone **29** was subjected to a Bamford–Stevens reaction,[36] being converted into its tosylhydrazone (**31**) which was heated with sodium ethylene glycolate. The product, after purification by sublimation, preparative thin layer chromatography, and glpc, proved to be identical in all respects with an authentic sample of (+)-α-eudesmol (**1**), separated from commercial eudesmol essentially as described by Seikel and Rowe,[37] and also by preparative thin layer chromatography.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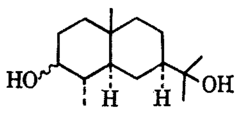
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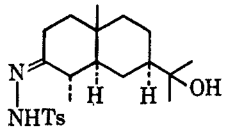
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[23] C. Djerassi, R. Riniker, and B. Riniker, *J. Am. Chem. Soc.*, **78**, 6362 (1956).

[24] *Cf.* J. W. Ralls and B. Riegel, *ibid.*, **76**, 4479 (1954).

[25] *Cf.* R. E. Ireland, T. I. Wrigley, and W. G. Young, *ibid.*, **80**, 4604 (1958).

[26] K. Bowden, I. M. Heilbron, E. R. H. Jones, and B. C. L. Weedon, *J. Chem. Soc.*, 39 (1946).

[27] *Cf.* H. B. Henbest and T. I. Wrigley, *ibid.*, 4596 (1957).

[28] L. Ruzicka, A. H. Wind, and D. R. Koolhaas, *Helv. Chim. Acta*, **14**, 1132 (1931); A. J. Birch and K. M. C. Mostyn[9a] have also described the ketone, but were unable to obtain it crystalline.

[29] C. Djerassi, W. Closson, and A. E. Lippman, *J. Am. Chem. Soc.*, **78**, 3163 (1956); C. Djerassi, *Bull. Soc. Chim. France*, 741 (1957). The amplitude (−56) is of the order (−60) expected for a *trans*-1-decalone of this type: W. Klyne, *Experientia*, **20**, 349 (1964).

[30] (a) K. R. Varma and S. C. Bhattacharyya, *Tetrahedron* **20**, 2927 (1964); we are indebted to Dr. Bhattacharyya, Poona, for an authentic specimen of (+)-β-eudesmol. (b) See also ref 7a (mp 76°).

[31] M. Sumimoto, H. Ito, H. Hirai, and K. Wada, *Chem. Ind.*, (London), 780 (1963).

[32] V. B. Zalkow, A. M. Shaligram, and L. H. Zalkow, *ibid.*, 194 (1964).

[33] D. H. R. Barton and E. J. Tarlton, *J. Chem. Soc.*, 3492 (1954).

[34] W. A. Ayer and W. I. Taylor, *ibid.*, 3027 (1955).

[35] *Cf.* D. H. R. Barton and C. H. Robinson, *ibid.*, 3045 (1954); A. J. Birch, H. Smith, and R. E. Thornton, *ibid.*, 1339 (1957).

[36] *Cf.* W. R. Bamford and T. S. Stevens, *ibid.*, 4735 (1952).

[37] M. K. Seikel and J. W. Rowe, *Phytochemistry*, **3**, 27 (1964).

Experimental Section[38]

(+)-11,12-Epoxy-11,12-dihydro-15-nor-α-cyperone (6).—(+)-15-Nor-α-cyperone[1,11a] (3.05 g) in anhydrous chloroform (15 ml) was added gradually to a freshly prepared solution of perbenzoic acid (2.11 g) in chloroform (87 ml) at 0°. After 24 hr at 0° the solution was shaken with aqueous sodium bicarbonate and with water, dried, and concentrated. The residual **epoxide** (6) distilled at 104–106° (0.50 mm) (2.80 g); n^{24}_D 1.5225; $[\alpha]_D$ +75.4° (*c* 3.1); λ_{max}^{hexane} 231 mμ (ε 13,200); ν_{max}^{film} 1681 (conjugated ketone C=O), 1629 (conjugated C=C), and 1250 cm^{-1} (epoxide).

Anal. Calcd for $C_{14}H_{20}O_2$: C, 76.36; H, 9.09. Found: C, 76.12; H, 9.10.

3-Hydroxy-15-nor-γ-eudesmol (7).—A cold solution of lithium aluminum hydride (0.82 g) in anhydrous ether (20 ml) was added slowly, with agitation, to the foregoing epoxide (3.2 g) in anhydrous ether (40 ml), at 0°. After 24 hr at 0° the mixture was decomposed in the usual way, and the product was isolated with ether. Evaporation afforded the diol **7** (3.1 g), a mixture of C_3 epimerides, as a syrup: bp 115–116° (0.1 mm); $[\alpha]_D$ +64.8° (*c* 5.1); λ_{max}^{MeOH} 208 mμ (ε 8930); $\nu_{max}^{CCl_4}$ 3510 (OH) and 1658 cm^{-1} (C=C).

Anal. Calcd for $C_{14}H_{24}O_2$: C, 75.00; H, 10.71. Found: C, 74.65; H, 10.50.

(+)-15-Norcarissone (8).—The foregoing diol (2.4 g) in dry chloroform (120 ml) was shaken with freshly prepared manganese dioxide[14] (25 g) for 24 hr. The suspension was filtered and the filtrate was concentrated *in vacuo*, leaving **(+)-15-norcarissone** (2.1 g): bp 107–108° (0.1 mm); $[\alpha]_D$ +102.7° (*c* 2.8); λ_{max}^{MeOH} 241 mμ (ε 10,530); $\nu_{max}^{CCl_4}$ 3704 (OH), 1672 (conjugated ketone C=O), and 1681 cm^{-1} (conjugated C=C).

Anal. Calcd for $C_{14}H_{22}O_2$: C, 75.68; H, 9.91. Found: C, 75.61; H, 9.90.

The **2,4-dinitrophenylhydrazone** crystallized from methanol in red needles: mp 136–137°, λ_{max}^{MeOH} 390 mμ (ε 21,900).

Anal. Calcd for $C_{20}H_{26}N_4O_5$: C, 59.70; H, 6.47; N, 13.93. Found: C, 59.76; H, 6.51; N, 14.08.

(+)-15-Norcarissone Ethylene Dithioketal (9).—(+)-15-Norcarissone (1.78 g) in methanol (25 ml) was mixed with ethanedithiol (1.28 g) and cooled to 0°. Freshly distilled boron trifluoride etherate (1 ml) was added; after 24 hr at 0° the methanol was removed *in vacuo* and the product was isolated with ether. The **ethylene dithioketal** distilled at 130–135° (0.2 mm) (2.1 g); it solidified easily and crystallized from petroleum ether in needles, mp 123°, undepressed by admixture with a sample of the product obtained by the reaction of the ethylene dithioketal **24** with methylmagnesium iodide (see below).

Condensation of (−)-Dihydrocarvone with 1-Diethylaminobutan-3-one Methiodide.—This condensation was effected using methylsulfinyl carbanion as base,[16] in a manner closely similar to that described for the (+) enantiomer.[1] The crude product from 21.3 g (−)-dihydrocarvone was distilled fractionally, affording a forerun (5.3 g) of unchanged ketone, followed by a fraction, bp 132–150° (0.5 mm) (13.6 g), which crystallized partially on keeping. Trituration with petroleum ether gave the ketol (**12**) (3.6 g): mp 105–106° (lit. mp 110–111°[39] and 106–107°[40]); $[\alpha]_D$ −56.1° (*c* 2.0) (lit.[39] $[\alpha]_D$ −58°); $\nu_{max}^{CCl_4}$ 3704 (OH), 1721 (C=O), 1647 and 894 cm^{-1} (C=CH$_2$); $\delta_{TMS}^{CCl_4}$ 1.18 (singlet, 3 H, angular CH$_3$), 1.68 (singlet, 2 H, =CCH$_3$), 2.18 (singlet, 1 H, OH), 2.45 (AB quartet, partly obscured, 2 H, *J* = 14 cps, CO-CH$_2$C<), and 4.65 (broad singlet, 2 H, C=CH$_2$); ORD in methanol (*c* 0.15) $[\phi]_{400}$ −320°, $[\phi]_{304}$ +1130°, $[\phi]_{261}$ −4220° (sh), $[\phi]_{213}$ −7850°.

Anal. Calcd for $C_{14}H_{22}O_2$: C, 75.63; H, 9.97. Found: C, 75.35; H, 9.73.

The noncrystalline material (*ca.* 10 g) on chromatography on silica gel (Davison, 200 g) gave, on elution with benzene–chloroform (10:1, followed by 3:2), a pale yellow liquid: bp 110–120° (0.2 mm) (2.8 g); $[\alpha]_D$ +77.3° (*c* 2.0); λ_{max}^{hexane} 235 mμ (ε 13,000); ν_{max}^{film} 1675 (conjugated C=O), 1618 (conjugated C=C), and 893 cm^{-1} (C=CH$_2$). Thin layer chromatography showed the presence of two components, the epimeric ketones **17** and **18** (see below). Elution with chloroform gave firstly an orange liquid (6.0 g), which crystallized from chloroform to give further ketol **12** (1.9 g), mp 103–104°, followed by the β-hydroxy sulfoxide **16** (0.77 g) as needles from petroleum ether: mp 115–116°; $[\alpha]_D$ +120° (*c* 2.0); λ_{max}^{EtOH} 205 mμ[41] (ε 1788); $\nu_{max}^{CCl_4}$ 3636 (free OH), 3472 (bonded OH), 1650 and 891 (C=CH$_2$), and 1020 cm^{-1} (S→O, H-bonded);[42] $\delta_{TMS}^{CCl_4}$ 0.95 (doublet, *J* = 4 cps, 3 H, CHCH_3), 1.74 (singlet, 3 H, =CCH$_3$), 2.60 (singlet, 3 H, CH$_3$S), 2.77 (AB quartet, *J* = 12 cps, 2 H, CH$_2$SO), 3.85 (singlet, 1 H, OH), and 4.70 (singlet, 2 H, C=CH$_2$). Hydrolysis with dilute aqueous alkali afforded (−)-dihydrocarvone and dimethyl sulfoxide.

Anal. Calcd for $C_{12}H_{22}O_2S$: C, 62.58; H, 9.63; S, 13.89. Found: C, 62.15; H, 9.48; S, 14.29.

Octalone 18. A.—A solution of the ketol **12** (3.0 g) in ethanol (50 ml) containing concentrated hydrochloric acid (6 ml) was kept at 0° for 10 days. Isolation with ether gave the octalone **18** (2.6 g): bp 110–114° (0.15 mm); $[\alpha]_D$ +176.0° (*c* 2.0) [lit. bp 85–95° (bath) (0.05 mm),[40] $[\alpha]_D$ +185°[39]]; λ_{max}^{hexane} 235 mμ (ε 13,100); $\nu_{max}^{CCl_4}$ 1678 (conjugated C=O), 1618 (conjugated C=C), and 895 cm^{-1} (C=CH$_2$); $\delta_{TMS}^{CCl_4}$ 1.26 (singlet, 3 H, angular CH$_3$), 1.72 (singlet, 3 H, C=CCH$_3$), 4.82 (unresolved multiplet, 2 H, C=CH$_2$), and 5.70 (singlet, 1 H, olefinic H); ORD in methanol [*c* 0.15 (500–300 mμ) and 0.015 (300–250 mμ)], $[\phi]_{500}$ +190°, $[\phi]_{400}$ +480°, $[\phi]_{355}$ +990°, $[\phi]_{312}$ −1160°, $[\phi]_{250}$ −470°.

Anal. Calcd for $C_{14}H_{20}O$: C, 82.30; H, 9.87. Found: C, 82.04; H, 9.61.

The semicarbazone crystallized from methanol in photochromic prisms: mp 221°, $[\alpha]_D$ +260° (*c* 0.45, pyridine).

Anal. Calcd for $C_{15}H_{23}N_3O$: C, 68.93; H, 8.87; N, 16.08. Found: C, 68.57; H, 8.72; N, 16.25.

B.—The mixture of epimeric ketones **17** and **18** was converted into the semicarbazones in the usual way. The crude product (5.0 g) was digested for some minutes with ethanol (50 ml) and the suspension filtered hot. The residue (2.4 g), methanol (115 ml), water (50 ml), petroleum ether (40 ml), oxalic acid (6.5 g), and 40% aqueous formaldehyde (33 ml) were refluxed for 3 hr. Water was added and the organic layer was separated, washed with water, dried, and concentrated. The residual ketone (1.2 g) distilled at 121–122° (0.4 mm) and was identical in all respects with octalone **18** obtained as in A.

Ozonolysis of Octalone 18. A.—The octalone **18** (2.0 g) in dry chloroform (20 ml) was ozonized at 0° for 15 hr. Water (100 ml) was added and the solvent was steam distilled. Then the cooled, aqueous residue was extracted several times with chloroform and the combined extracts were dried and evaporated. The residue distilled at 140° (0.2 mm) (1.3 g). Thin layer chromatography of the partly crystalline distillate showed the presence of two components, separable by preparative thin layer chromatography, with development with benzene–ethyl acetate (8:2). The fraction with higher R_f (**epoxide 20**) crystallized from petroleum ether in plates (0.4 g): mp 104–105.5°; $[\alpha]_D$ +4.0° (*c* 2.0); no ultraviolet absorption; $\nu_{max}^{CCl_4}$ 1715 (ketone C=O), 1260 and 925 cm^{-1} (epoxide CO);[43] $\delta_{TMS}^{CDCl_3}$ 1.12 (singlet, 3 H, angular methyl), 2.19 (singlet, 3 H, COCH$_3$), and 3.09 (singlet, 1 H, oxirane ring proton); ORD in methanol (*c* 0.30), $[\phi]_{400}$ −390°, $[\phi]_{323}$ −5000°, $[\phi]_{282}$ +8600°, $[\phi]_{245}$ +5550°, $[\phi]_{215}$ +7400°.

Anal. Calcd for $C_{13}H_{18}O_3$: C, 70.24; H, 8.16. Found: C, 70.21; H, 7.91.

The fraction with higher R_f (**diketone 19**) crystallized from petroleum ether (bp 40–60°)–ether in prisms: mp 56–57° (0.2 g); $[\alpha]_D$ +156° (*c* 2.0); λ_{max}^{EtOH} 242 mμ (ε 14,100); $\nu_{max}^{CCl_4}$ 1720 (saturated ketone C=O), 1680 (conjugated ketone C=O), and 1620 cm^{-1} (conjugated C=C); $\delta_{TMS}^{CDCl_3}$ 1.26 (singlet, 3 H, angular

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[38] Melting points and boiling points are uncorrected. Ultraviolet spectra were measured on a Unicam SP800, and infrared spectra were measured on Perkin-Elmer Infracord 137 and 237, and Unicam SP200G instruments. Nmr spectra were determined on a Perkin-Elmer R10 spectrometer at 60 Mcps, in deuteriochloroform solution, using tetramethylsilane as internal standard. ORD measurements were made on a Bellingham–Stanley/Bendix–Ericsson Polarmatic 62 spectropolarimeter. Glpc analyses were performed on a Pye argon chromatograph, using a 30% PEGA on 100–120 mesh Celite column, on a Wilkens "Aerograph" Model 600-C (10% Carbowax on 60–80° Chromosorb W), and on a Wilkens "Aerograph Autoprep" Model A-700 instruments. Tlc was performed on silica gel or silica gel impregnated with silver nitrate. Preparative tlc was on Merck silica gel HF 254, using 1-mm layers. Spots and bands were located with ultraviolet light. Optical rotations are in chloroform at 25°. Petroleum ether refers to the fraction bp 60–80°.

[39] D. W. Theobald, *Tetrahedron Letters*, 969 (1966); *Tetrahedron*, **22**, 2869 (1966).

[40] J. A. Marshall, W. I. Fanta, and H. Roebke, *J. Org. Chem.*, **31**, 1016 (1966).

[41] *Cf.* H. P. Koch, *J. Chem. Soc.*, 2892 (1950); G. Leandri, A. Mangini, and R. Passerini, *ibid.*, 1386 (1957).

[42] *Cf.* T. Cairns, G. Eglinton, and D. T. Gibson, *Spectrochim. Acta*, **20**, 31 (1964).

[43] L. J. Bellamy, "The Infrared Spectra of Complex Molecules," Methuen and Co. Ltd., London, 1958, p 115.

CH_3), 2.14 (singlet, 3 H, $COCH_3$), and 5.83 (singlet, 1 H, olefinic H); ORD in methanol [c 0.06 (500–300 mμ) and 0.03 (300–196 mμ)], $[\phi]_{500}$ +350°, $[\phi]_{400}$ +380°, $[\phi]_{355}$ +1040°, $[\phi]_{306}$ −7000°, $[\phi]_{256}$ +44000°, $[\phi]_{226}$ −9000°, $[\phi]_{211}$ −14600°, $[\phi]_{196}$ −35000°.

Anal. Calcd for $C_{13}H_{18}O_2$: C, 75.69; H, 8.80. Found: C, 75.48; H, 8.87.

B.—The octalone **18** (2.0 g) in chloroform (20 ml) and pyridine (0.8 ml, 1 mole) was ozonized for 15 hr at 0°. Zinc dust was added, with ice cooling, and the mixture was shaken for 20 min, filtered, and treated with water (100 ml). The solvents were removed by steam distillation, and the residue was extracted with chloroform. The extract was dried and concentrated *in vacuo*, to yield a pale yellow liquid, bp 140° (0.3 mm) (1.6 g), which solidified readily and crystallized from petroleum ether (bp 40–60°)–ether in prisms, mp 55–56°, identical with the diketone **19** described above.

Epimerization of Diketone 19.—The diketone (100 mg) in ethanol (2 ml) containing concentrated hydrochloric acid (0.2 ml) was kept for 24 hr, then poured into water. Ether extraction afforded, after evaporation, **diketone 21** as needles from petroleum ether (42 mg): mp 107–107.5°; $[\alpha]_D$ +83° (c 2.0); $\lambda_{\max}^{\mathrm{EtOH}}$ 238 mμ (ϵ 16,080); $\nu_{\max}^{\mathrm{CCl_4}}$ 1720 (saturated ketone C=O), 1680 (conjugated ketone C=O), and 1620 cm^{-1} (conjugated C=C); $\delta_{\mathrm{TMS}}^{\mathrm{CCl_4}}$ 1.26 (singlet, 3 H, angular CH_3), 2.12 (singlet, 3 H, $COCH_3$), and 5.62 (singlet, 1 H, olefinic H); ORD in methanol [c 0.074 (500–270 mμ) and 0.024 (270–195 mμ)], $[\phi]_{500}$ +190°, $[\phi]_{400}$ +310°, $[\phi]_{381}$ −290°, $[\phi]_{300}$ +2800°, $[\phi]_{270}$ +14300°, $[\phi]_{249}$ +32000°, $[\phi]_{218}$ −39000°, $[\phi]_{195}$ −31400°.

Anal. Calcd for $C_{13}H_{18}O_2$: C, 75.69; H, 8.80. Found: C, 75.39; H, 8.96.

Ozonolysis of Ketol 12.—The ketol **12** (3.0 g) in dry chloroform (20 ml) was ozonized for 18 hr at 0°. Water (100 ml) was added and the solvent was steam distilled. Then the cooled residue was extracted with chloroform, and the dried extract was concentrated *in vacuo*, leaving the diketo alcohol **23** (2.9 g), which crystallized from petroleum ether–benzene (1:1) in needles: mp 142–143°; $[\alpha]_D$ −42° (c 2.0); $\nu_{\max}^{\mathrm{CHCl_3}}$ 3610 (free OH), 3470 (bonded OH), and 1715 cm^{-1} (saturated ketone C=O); $\delta_{\mathrm{TMS}}^{\mathrm{CHCl_3-CCl_4}}$ 1.20 (singlet, 3 H, angular CH_3), 2.12 (singlet, 3 H, $COCH_3$), and 2.20 (singlet, 1 H, OH); ORD in methanol (c 0.065), $[\phi]_{500}$ +350°, $[\phi]_{400}$ +610°, $[\phi]_{273}$ +3970°, $[\phi]_{249}$ −5000°, $[\phi]_{218}$ +25000°.

Anal. Calcd for $C_{13}H_{20}O_3$: C, 69.61; H, 8.99. Found: C, 69.63; H, 8.97.

Dehydration of Diketo Alcohol 23.—The above diketo alcohol (5.8 g) in ethanol (80 ml), containing concentrated hydrochloric acid (10 ml), was kept at 0° for 7 days. Isolation with ether gave a semicrystalline mass (4.9 g) of the diketone **21**, which separated from petroleum ether in needles, mp 106–107°, identical with the product described above (mixture melting point comparison).

Reaction of Diketone 21 with Ethanedithiol.—Diketone **21** (4.8 g) and ethanedithiol (1.95 ml) were dissolved in methanol (60 ml) and treated at 0° with boron trifluoride etherate (3.3 ml). After 24 hr at 0° water (60 ml) was added and the product was isolated by chloroform extraction. Evaporation of the washed ($NaHCO_3$) and dried extracts *in vacuo* left a viscous, yellow liquid (3.7 g), which was chromatographed on alumina (Woelm neutral, activity III, 80 g). Elution with petroleum ether–benzene (4:1) afforded, after solvent evaporation, a waxy solid (2.0 g), which crystallized from petroleum ether in prisms of the **ethylene dithioketal 24**: mp 85–86.5°; $[\alpha]_D$ +50.5° (c 2.0); $\lambda_{\max}^{\mathrm{hexane}}$ 245 mμ (ϵ 900);[44] $\nu_{\max}^{\mathrm{CCl_4}}$ 1715 (saturated ketone C=O), 1645 cm^{-1} (C=C); $\delta_{\mathrm{TMS}}^{\mathrm{CCl_4}}$ 1.08 (singlet, 3 H, angular CH_3), 2.07 (singlet, 3 H, $COCH_3$), 3.26 (multiplet, 4 H, SCH_2CH_2S), and 5.47 (singlet, 1 H, olefinic H); ORD in methanol (c 0.04), $[\phi]_{500}$ +180°, $[\phi]_{400}$ +220°, $[\phi]_{302}$ −990°, $[\phi]_{269}$ −3900°, $[\phi]_{249}$ −2300°, $[\phi]_{216}$ −31000°.

Anal. Calcd for $C_{15}H_{22}OS_2$: C, 63.81; H, 7.85; S, 22.67. Found: C, 63.57; H, 7.94; S, 23.03.

Further elution of the chromatogram with petroleum ether–benzene (1:1) gave a gum, which was triturated with ether and kept at 0° for several hours. A crystalline solid (0.4 g) separated; it was collected, washed with ether, and purified by preparative thin layer chromatography. Elution with petroleum ether (bp 40–60°) and crystallization from petroleum ether–benzene (1:1) gave the **bis(ethylene dithioketal) 25** (0.4 g) as prisms: mp 170–170.5°; $[\alpha]_D$ +93.7° (c 2.0); $\lambda_{\max}^{\mathrm{hexane}}$ 248 mμ (ϵ 1700);[44] $\nu_{\max}^{\mathrm{Nujol}}$ 1645, 847 cm^{-1} (C=C); $\delta_{\mathrm{TMS}}^{\mathrm{CHCl_3}}$ 1.07 (singlet, 3 H, angular CH_3), 1.75 (singlet, 3 H, $CH_3C{<}^{S}_{S}$), 3.30 (multiplet, 8 H, SCH_2CH_2S), and 5.55 (singlet, 1 H, olefinic H); ORD in methanol–dioxane (4:1) (c 0.04), $[\phi]_{500}$ +260° $[\phi]_{400}$ +650°, $[\phi]_{279}$ +3900°, $[\phi]_{250}$ −6500°, $[\phi]_{216}$ +25000°.

Anal. Calcd for $C_{17}H_{26}S_4$: C, 56.97; H, 7.06; S, 35.72. Found: C, 56.78; H, 7.39; S, 35.11.

Reaction of Methyl Ketone 24 with Methylmagnesium Iodide.—A Grignard reagent was prepared from magnesium (0.45 g), dry ether (20 ml), and methyl iodide (3.5 g). The methyl ketone **24** (1.5 g) in dry ether (25 ml) was added gradually, with stirring at 0°; on completion of the addition the mixture was refluxed for 30 min on the steam bath, cooled, and decomposed with saturated aqueous ammonium chloride. The ether layer was separated, washed with water, dried, and concentrated, leaving the tertiary alcohol **9**, which crystallized from petroleum ether in needles (0.95 g): mp 123–123.5°; $[\alpha]_D$ +93.6° (c 2.0); $\lambda_{\max}^{\mathrm{hexane}}$ 244 mμ (ϵ 800);[44] $\nu_{\max}^{\mathrm{CCl_4}}$ 3620 (free OH), 3500 (bonded OH), and 1645 cm^{-1} (C=C); $\delta_{\mathrm{TMS}}^{\mathrm{CCl_4}}$ 1.07 (singlet, 3 H, angular CH_3), 1.14 [singlet, 6 H, $C(CH_3)_2$], 3.28 (multiplet, 4 H, SCH_2CH_2S), and 5.48 (singlet, 1 H, olefinic H); ORD in methanol (c 0.065), $[\phi]_{500}$ +350°, $[\phi]_{610}$ +400°, $[\phi]_{273}$ +3970, $[\phi]_{249}$ −50000°.

Anal. Calcd for $C_{16}H_{26}OS_2$: C, 64.40; H, 8.78; S, 21.45. Found: C, 64.20; H, 8.70; S, 21.51.

15-Nor-γ-eudesmol (**10**). **A.**[25]—To a stirred solution of the ethylene dithioketal **9** (500 mg) in dry ether (20 ml) and liquid ammonia (50 ml) was added sodium metal (500 mg). The mixture was stirred for 10 min and then treated with sufficient ethanol to dispel the blue color. The ammonia was allowed to evaporate, and water and ether were added. The ether layer was separated, washed with water, dried, and concentrated *in vacuo*. The residual **15-nor-γ-eudesmol** (**10**) distilled at 88–90° (0.15 mm) (395 mg) (single peak on gas chromatography): $[\alpha]_D$ +47.8° (c 2.0); $\lambda_{\max}^{\mathrm{EtOH}}$ 205 mμ (ϵ 6040); $\nu_{\max}^{\mathrm{film}}$ 3571 (OH), 1661, 807 cm^{-1} ($R_1R_2C{=}CHR_3$); $\delta_{\mathrm{TMS}}^{\mathrm{CDCl_3}}$ 1.05 (singlet, 3 H, angular CH_3), 1.20 [singlet, 6 H, $C(CH_3)_2$], and 5.34 (broad, 1 H, =CH); ORD in methanol (c 0.12), $[\phi]_{500}$ +110°, $[\phi]_{400}$ +180°, $[\phi]_{300}$ +480°, $[\phi]_{250}$ +1090°, $[\phi]_{219}$ +1900°.

Anal. Calcd for $C_{14}H_{24}O$: C, 80.71; H, 11.61; O, 7.68. Found: C, 80.36; H, 11.66; O, 8.09.

B.—W-2 Raney nickel was partially poisoned by refluxing in 90% aqueous ethanol containing pyrrolidine (1 ml per 3 g of nickel) for 5 hr.[45] The catalyst was washed well by decantation with 90% ethanol. The ethylene dithioketal **9** (400 mg) was refluxed with the poisoned catalyst (*ca.* 6 g) for 16 hr under nitrogen. Removal of the catalyst and concentration of the filtrate gave **15-nor-γ-eudesmol**, bp 90° (0.16 mm) (251 mg), identical with that obtained as described under A.

Hydroboration–Oxidation of 15-Nor-γ-eudesmol.—The apparatus described by Brown and Zweifel[46] for the external generation of diborane was used. Boron trifluoride etherate (15 ml) in dry diglyme (10 ml) was added dropwise to a stirred solution of sodium borohydride (1.14 g) in diglyme (20 ml). The diborane formed was swept by a slow nitrogen stream through a solution of 15-nor-γ-eudesmol (272 mg) in dry tetrahydrofuran (10 ml), at 0°. Toward the end the diborane generator was heated to 70–80°. The tetrahydrofuran solution was treated with water (5 ml), 4 *N* aqueous sodium hydroxide (10 ml), and 30% hydrogen peroxide (10 ml), with shaking and ice cooling, and kept overnight at room temperature. Water and ether were added, and the aqueous layer was saturated with salt. The product, a mixture of **epimeric diols 26**, was isolated by several ether extractions; evaporation afforded a viscous liquid (301 mg), which showed no C=C absorption in the infrared region. The product was dissolved in acetone (10 ml) and titrated with Jones reagent[26] at 0° until an orange color persisted. After keeping for 20 min water was added and the product was isolated with ether. Evaporation of the solvent left a yellow liquid (280 mg), a mixture of the expected *cis*- and *trans*-1-decalones. The crude product, in benzene, was poured onto a column of Woelm basic alumina (activity I, 10 g); after 24 hr, elution with benzene–chloroform (1:1) was effected, affording, after evaporation, **7β-(1-hydroxy-1-methylethyl)-10β-methyl-*trans*-4-decalone** (**27**), which crystallized from petroleum ether in prisms: mp 119–120° (225 mg); $[\alpha]_D$ +7.1° (c 2.0); $\nu_{\max}^{\mathrm{CHCl_3}}$ 3600 (free OH), 3450

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[44] *Cf.* D. A. Lightner, C. Djerassi, K. Takeda, K. Kuriyama, and T. Komeno, *Tetrahedron*, **21**, 1581 (1965).

[45] Compare W. Oroshnik, G. Karmas, and A. D. Mebane, *J. Am. Chem. Soc.*, **74**, 295 (1952).

[46] H. C. Brown and G. Zweifel, *ibid.*, **83**, 2544 (1961).

(bonded OH), and 1705 cm^{-1} (saturated ketone C=O); $\delta_{TMS}^{CDCl_3}$ 0.78 (singlet, 3 H, angular CH_3), 1.20 [singlet, 6 H, $C(CH_3)_2$], and 1.63 (singlet, 1 H, OH); ORD in methanol (*c* 0.09), $[\phi]_{500}$ +50°, $[\phi]_{400}$ −50°, $[\phi]_{301}$ −2150°, $[\phi]_{264}$ +3450°, $[\phi]_{210}$ +1500°. This product was identical in all respects with the ketone obtained by ozonolysis of commercial eudesmol (see below).

Anal. Calcd for $C_{14}H_{24}O_2$: C, 75.00; H, 10.71. Found: C, 75.06; H, 10.60.

Ozonolysis of Commercial Eudesmol.[9a,28]—Eudesmol (1.0 g) in dry chloroform (15 ml) was ozonized for 6 hr at 0°. Water was added and the solvent was steam distilled. The aqueous residue was cooled and extracted several times with chloroform. Evaporation of the combined, dried extracts afforded a liquid residue (1.0 g), thin layer chromatography of which showed the presence of several components. The product, in benzene, was chromatographed on Woelm neutral alumina (activity III, 25 g). Elution with benzene yielded the ketol **27** (95 mg), which solidified, and crystallized from petroleum ether in prisms, mp 118–119° (lit.[28] mp 119-120°), identical in all respects with the synthetic material described above.

(+)-β-**Eudesmol** (**2**).—Dimethyl sulfoxide (4 ml) was added to powdered sodium hydride (160 mg) and the whole was stirred at 75–80° under dry nitrogen for 45 min. The clear solution was cooled in ice-water, and methyltriphenylphosphonium bromide (2.4 g) in dimethyl sulfoxide (5 ml) was added. The yellow ylid solution was stirred at ambient temperature for 10 min; the ketol **27** (150 mg) in dimethyl sulfoxide (4 ml) was then added, and the mixture was stirred at 50–60° for 30 hr under nitrogen.[47] The cooled system was decomposed with ice-water, and the product was isolated with ether. The extracts were well washed with water, dried, and concentrated. The residue was a crystalline mass (356 mg) containing an appreciable amount of triphenylphosphine oxide. It was resolved by preparative thin layer chromatography, with elution by benzene–ethyl acetate (9:1). The more mobile fraction was a white, waxy solid (113 mg), identical in all respects (infrared spectrum, tlc mobility, glpc retention time, nmr spectrum) with natural (+)-β-eudesmol.[30] The synthetic product was further purified by crystallization from petroleum ether (bp 40–60°), from which it separated in spongy needles, mp 79–80°, or by vacuum sublimation, as needles: mp 79–80°; $[\alpha]_D$ +56.6° (*c* 2.0) (lit.[30a] mp 80–81°, $[\alpha]_D$ +58.0°); $\delta_{TMS}^{CCl_4}$ 0.72 (singlet, 3 H, angular CH_3), 1.18 [singlet, 6 H, $C(CH_3)_2$], 4.47 and 4.72 (singlets, 2 H, $C{=}CH_2$); $\nu_{max}^{CCl_4}$ 3618 (free OH), 3480 (bonded OH, broad), 1650 and 889 ($C{=}CH_2$), 1380 and 1370 cm^{-1} [$C(CH_3)_2$] [lit.[7b] $\delta_{TMS}^{DCCl_2}$ 0.69 (angular CH_3), 4.42 and 4.77 ($=CH_2$); lit.[30a] 0.7 (angular CH_3), 1.2 [$C(CH_3)_2$], 4.47 and 4.73 ppm ($C{=}CH_2$)].

(−)-*trans*-**Dihydrocarissone** (**29**).—(+)-Carissone (**28**) was isolated from tubers of *Carissa lanceolata*,[48] as described by Mohr. Schindler, and Reichstein.[49] The ketone (472 mg) in dry ether (10 ml) was added to a stirred solution of lithium metal (100 mg) in liquid ammonia (100 ml). After 40 min, solid ammonium chloride was added and the ammonia was allowed to evaporate. Addition of water and ether extraction gave, after evaporation, a solid, mp 72–82° (451 mg), thin layer chromatography of which showed the presence of one major and two minor components. The crude product (448 mg) in purified acetone (10 ml) was titrated at 0° with Jones reagent.[26] Dilution with ice-water and ether extraction afforded a crystalline solid, mp 107–108° (415 mg), showing a single spot on tlc. A benzene solution of the product was filtered through alumina and evaporated, and the residue was crystallized from petroleum ether, from which the product separated in needles: mp 109–110°; $[\alpha]_D$ −11.7° (*c* 2.0); $\nu_{max}^{CCl_4}$ 3615, 1715 cm^{-1}; $\delta_{TMS}^{CCl_4}$ 6.91 (singlet, 3 H, angular CH_3), 1.02 and 1.10 (doublet, J = 5 cps, 3 H, C-4—CH_3), 1.18 [singlet, 6 H, $(CH_3)_2C$], and 2.42 (singlet, 1 H, OH); ORD in methanol (*c* 0.10), $[\phi]_{400}$ −50°, $[\phi]_{303}$ +2500°, $[\phi]_{263}$ −4550° sh, $[\phi]_{208}$ −5250°. Subsequent experimentation showed that the crude reduction product (238 mg) could be satisfactorily purified by equilibration with concentrated hydrochloric acid (0.2 ml) in ethanol (5 ml) for 12 hr at 0°.

Anal. Calcd for $C_{15}H_{26}O_2$: C, 75.58; H, 11.00. Found: C, 75.61; H, 10.86.

trans-**Dihydrocarissone Tosylhydrazone** (**31**).—A solution of the foregoing ketone (100 mg), toluene-*p*-sulfonylhydrazine (90 mg), and concentrated hydrochloric acid (1 drop) in ethanol (5 ml) was refluxed for 1 hr. Removal of the solvent *in vacuo* gave the hydrazone which crystallized from benzene in needles: mp 143–144° dec (143 mg), $[\alpha]_D$ +37.7° (*c* 2.0).

Anal. Calcd for $C_{22}H_{34}N_2O_3S$: N, 6.89; S, 7.87. Found: N, 6.81; S, 7.97.

(+)-α-**Eudesmol** (**1**).—The above tosylhydrazone (230 mg) in ethylene glycol (10 ml) containing dissolved sodium metal (250 mg) was heated under nitrogen at 170–190° (bath) for 1 hr, then poured into water.[36] The product, isolated with ether, was a pale yellow solid (151 mg); it was sublimed twice at 16 mm (bath temperature 90°) to give needles of substantially pure (+)-α-eudesmol (51 mg). Thin layer and gas chromatography of the product, and its nmr spectrum, indicated that it contained a trace of impurity. Further purification was effected by a combination of preparative thin layer (on silica gel impregnated with silver nitrate[50]) and gas chromatography, leading to pure (+)-α-eudesmol (45 mg): mp 74–75°; $[\alpha]_D$ +28.5° (*c* 1.2) (lit.[7a] mp 75°, $[\alpha]_D$ +28.6°); $\delta_{TMS}^{CDCl_3}$ 0.79 (singlet, 3 H, angular CH_3), 1.22 [singlet, 6 H, $(CH_3)_2C$], 1.47 (singlet, 1 H, OH), 1.63 (broad singlet, 3 H, $=CCH_3$), and 5.45 (unresolved multiplet, 1 H, =CH) (lit.[7b] $\delta_{TMS}^{CDCl_3}$ 0.76 and 5.27); ORD in methanol (*c* 0.05), $[\phi]_{400}$ +20°, $[\phi]_{300}$ +15°, $[\phi]_{250}$ −90°, $[\phi]_{216}$ −2600°. This product was identical in every respect (tlc, glpc, and infrared comparison) with an authentic specimen of (+)-α-eudesmol isolated from a sample of commercial eudesmol, containing α and β isomers only, as described by Seikel and Rowe.[37] Alternatively, separation was effected more rapidly and efficiently by preparative thin layer chromatography on silica gel impregnated with silver nitrate.[50] For this purpose the silica gel plates were sprayed with 13% aqueous silver nitrate, then dried at 120° for 30 min, cooled, and used immediately. They were streaked manually with 25–30 mg of commercial eudesmol per plate (20 × 20 cm, layer 1 mm thick), and developed with benzene–ethyl acetate (8:2). Two zones were observed; the upper one, on removal, extraction with chloroform, concentration, and sublimation, afforded (+)-α-eudesmol: mp 74–75°, $[\alpha]_D$ +29.0°.

Anal. Calcd for $C_{15}H_{26}O$: C, 81.02; H, 11.79. Found: C, 80.46; H, 11.97.

Registry No.—**1**, 473-16-5; **2**, 4895-24-3; **6**, 13065-10-6; **7**, 13065-11-7; **8**, 13085-21-7; **8** 2,4-dinitrophenylhydrazone, 13094-93-4; **9**, 4895-28-7; **10**, 4895-29-8; **12**, 4895-25-4; **16**, 13065-14-0; **17**, 13005-23-9; **18**, 5208-62-8; **18** semicarbazone, 13065-16-2; **19**, 13065-17-3; **20**, 13065-18-4; **21**, 4895-27-6; **23**, 4895-26-5; **24**, 5003-95-2; **25**, 13094-94-5; **27**, 4895-32-3; **29**, 13065-22-0; **31**, 13085-25-1.

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(47) Compare R. Greenwald, M. Chaykovsky, and E. J. Corey, *J. Org. Chem.*, **28**, 1128 (1963).

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(49) K. Mohr, O. Schindler, and T. Reichstein, *Helv. Chim. Acta*, **37**, 462 (1954).

(50) *Cf., inter alia*, A. S. Gupta and S. Dev, *J. Chromatog.*, **12**, 189 (1963); E. von Rudloff, *Chem. Ind.* (London), 2126 (1964).