520. *Experiments on the Synthesis of Diterpenes. Part I.*
A Total Synthesis of (±)-Totarol.

By J. A. Barltrop and N. A. J. Rogers.

Some preliminary synthetical experiments on tricyclic diterpenoid resinols are described. The structure of the diterpenoid totarol has been confirmed as (I) by a total synthesis.

Totarol, a phenolic tricyclic diterpene, was first isolated from the wood of the Totara tree (*Podocarpus totara*) by Easterfield and McDowell.[1] A series of investigations by Short and his co-workers[2] led to the proposal that the structure (I) represented the constitution of totarol. An alternative structure (II), proposed by Brandt and Thomas,[3] which, unlike (I) obeys the isoprene rule, can be used as a basis for the interpretation of most of the chemical results but is difficult to reconcile with the spectroscopic data. Totarol has the infrared spectrum of a phenol possessing a very hindered hydroxyl group,[2] whereas the compound (II) would be expected to exhibit normal phenolic behaviour. Further, in the region 11·5—14·5 μ, totarol has the absorption expected of a 1 : 2 : 3 : 4- rather than a 1 : 2 : 3 : 5-tetrasubstituted benzene, as is shown in the Table.

Infrared spectra of totarol and related compounds in the region 11·5—14·5 μ.

Compound:	XV, R = OMe	XIII, R = OMe	XIV, R = OMe	XXIII [a]	IV	Totarol (I)
Band I	11·6, 11·8	11·75	11·7	11·65	11·8	—
Band II	12·5	—	—	12·55	—	12·52
Band III	—	12·8	12·75	—	12·8	—
Band IV	—	14·6	14·4	—	14·4	—

[a] Present authors' unpublished work.

Band I, which is associated with the out-of plane vibrational mode of a single aromatic C–H bond, and the bands III and IV which are associated with the corresponding mode for three adjacent aromatic C–H bonds, are seen to be absent in the spectrum of totarol, while band II, associated with the corresponding mode for two adjacent C–H bonds, is present.

A total synthesis of (±)-totarol, a preliminary account of which has been published,[4] confirms the spectroscopic assignments and shows that the diterpene has, in fact, the constitution (I).

[1] Easterfield and McDowell, *Trans. New Zealand Inst.*, 1911, **43**, 55; 1915, **48**, 578.
[2] Short, Stromberg, and Wiles, *J.*, 1936, 319; Short and Stromberg, *J.*, 1937, 576; Short and Wang, *J.*, 1950, 991; 1951, 2979.
[3] Brandt and Thomas, *New Zealand J. Sci. Technol.*, 1951, **33**, B, 30.
[4] Barltrop and Rogers, *Chem. and Ind.*, 1957, 20.

We first tried to synthesise the tricyclic ketone (VI), in which, it was hoped, the 10-keto-function would ensure a *trans*-AB-ring-junction. The annexed route was chosen partly because of the ready availability of 2-acetyl-1 : 3 : 3-trimethyl*cyclo*hexene and *m*-methoxy-benzaldehyde. These two substances readily gave the benzylidene derivative (III), which
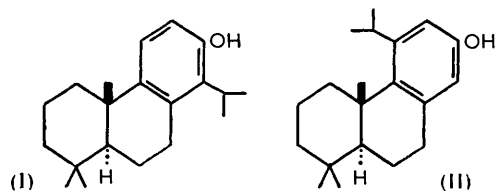
was hydrogenated over Raney nickel to 2-(β-*m*-methoxyphenylpropionyl)-1 : 3 : 3-tri-methyl*cyclo*hexene (IV). Several attempts were made to cyclise this compound, none of which gave the desired product (V). The use of aluminium chloride in nitrobenzene, saturated with hydrogen chloride, or of phosphoric acid at elevated temperatures [5] gave, as the main product, 5-methoxyind an-1-one (VII). With aluminium chloride in boiling benzene,[6] two products were obtained, probably 1 : 3 : 3-trimethyl-1-phenyl*cyclo*hexane (VIII) and 2-(β-*m*-methoxyphenylpropionyl)-1 : 3 : 3-trimethyl-1-phenyl*cyclo*hexane (IX). It is evident that the action of Lewis acids on the αβ-unsaturated ketone (IV) induces a reverse Darzens reaction, both products of this fission having been observed in the above reactions.

At this time it became clear that a 1- or 10-keto-function in an octahydro-phenanthrene does not necessarily ensure a *trans*-AB-ring-junction. Indeed, there is now considerable evidence that Stork and Burgstahler's ketone [5] (X) is partly [7] or even largely [8] the AB-*cis*-compound. Further, the ketone (XI) obtained by Gutsche and Johnson [6]
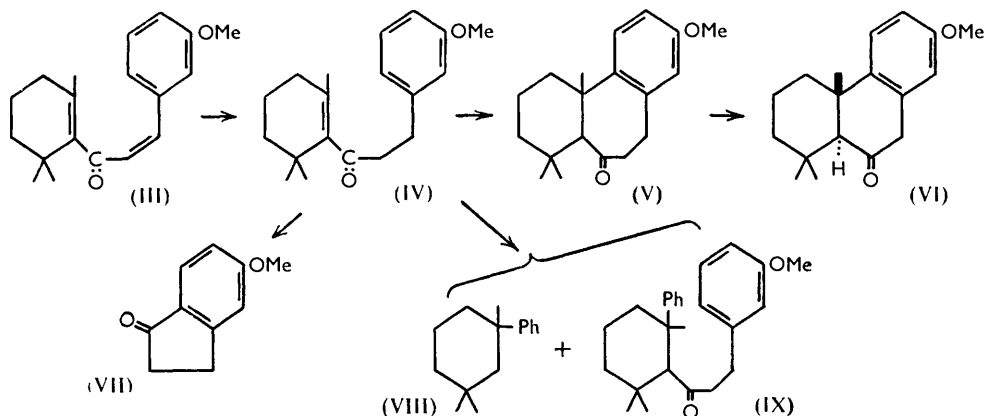
was shown to be a mixture of *cis*- and *trans*-isomers, as was the keto-acid (XII) obtained by Parham, Wheeler, and Dodson.[6]

Attempts to synthesise the intermediate (XIV; R = MeO) from 2 : 2 : 6-trimethyl-*cyclo*hexanone and 3-methoxyphenethylmagnesium bromide gave, as the principal products, 2 : 2 : 6-trimethyl*cyclo*hexanol, and 1 : 4-di-(*m*-methoxyphenyl)butane. Similar behaviour has been noted with other highly hindered ketones in the Grignard reaction.[9,10]

[5] Stork and Burgstahler, *J. Amer. Chem. Soc.*, 1951, **73**, 3544.
[6] Gutsche and Johnson, *ibid.*, 1946, **68**, 2239; Parham, Wheeler, and Dodson, *ibid.*, 1955, **77**, 1166.
[7] Saha, Ganguly, and Dutta, *Chem. and Ind.*, 1956, 412.
[8] Barltrop and Day, unpublished work.
[9] Conant and Blatt, *J. Amer. Chem. Soc.*, 1929, **51**, 1227; Johnson, Banerjee, Schneider, Gutsche, Shelberg, and Chinn, *ibid.*, 1952, **74**, 2841.
[10] King, King, and Topliss, *J.*, 1957, 573.

However, the reactions of several acetylenic derivatives with 2 : 2 : 6-trimethyl*cyclo*-hexanone, to give the corresponding ethynylcarbinols in high yield, have been recorded; [10, 11]

(X)   (XI)   (XII)
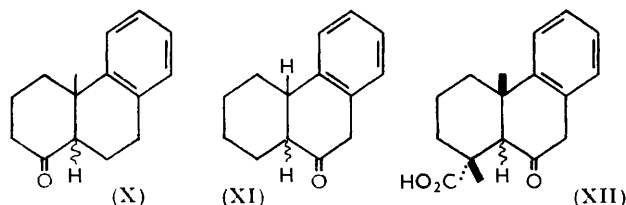
this ketone with potassium phenylacetylide in liquid ammonia indeed gave 2 : 2 : 6-tri-methyl-1-phenylethynyl*cyclo*hexanol (XIII; R = H), in 50% yield. This was hydro-genated over 5% palladised charcoal to 2 : 2 : 6-trimethyl-1-phenethyl*cyclo*hexanol (XIV; R = H) in quantitative yield. Cyclisation with polyphosphoric acid afforded 1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-octahydro-1 : 1 : 12-trimethylphenanthrene (XV; R = H).

With potassium *m*-methoxyphenylacetylide, 2 : 2 : 6-trimethyl*cyclo*hexanone gave a high yield of the corresponding ethynylcarbinol (XIII; R = OMe). Hydrogenation over 5% palladised charcoal and then cyclisation with polyphosphoric acid gave *trans*-1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-octahydro-7-methoxy-1 : 1 : 12-trimethylphenanthrene (XV; R = OMe). This substance readily crystallised after distillation. Chromatography on active alumina gave only one isolatable product, the infrared spectra of the fractions collected during this chromatography suggesting that the material was homogeneous


(XIII)   (XIV)   (XV)

(XVI)   (XVIII)   (XX)

(XVII)   (XIX)   (I)
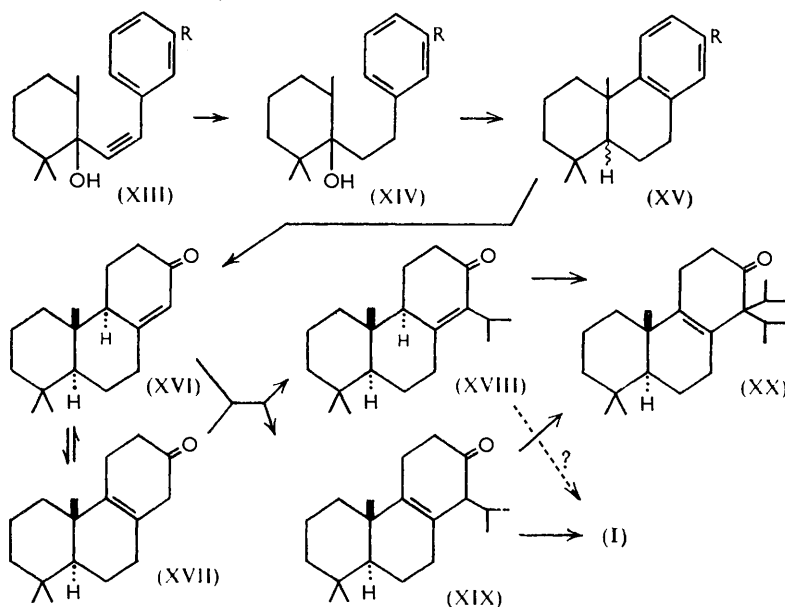
(cf. King *et al.*[10]). Reduction of this product with lithium in liquid ammonia [12] gave an enol ether, fission of which with dilute sulphuric acid, gave a mixture of podocarp-8(14)-(XVI) and podocarp-13(14)-en-7-one (XVII), which were separable by chromatography on alumina. The βγ-unsaturated ketone (XVII) was the only product isolated when the enol ether was hydrolysed with aqueous-alcoholic oxalic acid.[12]

[11] Campbell, *J. Amer. Chem. Soc.*, 1938, **60**, 2282; Sobotka and Chanley, *ibid.*, 1949, **71**, 4136; Milas, Macdonald, and Black, *ibid.*, 1948, **70**, 1829; Attenburrow, Cameron, Chapman, Evans, Jansen, and Walker, *J.*, 1952, 1094.
[12] Wilds and Nelson, *J. Amer. Chem. Soc.*, 1953, **75**, 5360, 5366

The dextrorotatory form of ketone (XVI) was obtained by Hosking,[13] and by Büchi and Jeger,[14] as a degradation product of the bicyclic diterpene manööl. A sample of the semicarbazone was kindly made available by Professor Jeger; its infrared spectrum, in Nujol mull, was very similar to that of the synthetic derivative, the slight differences being attributable to the small differences between the crystal structures of the (+)- and the (±)-compound. The low solubility of these substances rendered determination of their infrared spectra in solution impracticable, and a small quantity of the dextrorotatory

(XXI)   (XXII)   (XXIII)
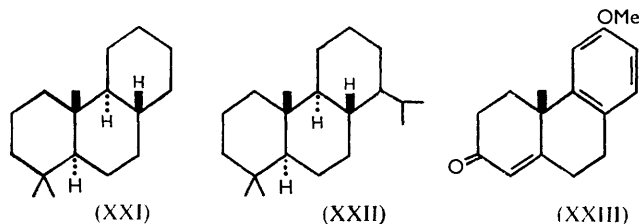
material was therefore hydrolysed, the unsaturated ketone being obtained, in low yield, by chromatography of the product. The infrared spectrum of this material, in solution in carbon disulphide, was identical with that of the synthetic ketone (XVI).

Treatment of either isomer (XVI) or (XVII) with sodium *tert.*-amyloxide in benzene,[15] followed by refluxing under nitrogen with *iso*propyl iodide, gave a mixture of totar-8(14)-(XVIII) and totar-13(14)-en-7-one (XIX), the latter predominating. These ketones could not be separated by chromatography on alumina. That alkylation had occurred at position 8 and not at position 6 was shown by the position of the conjugated carbonyl band at 251 mμ.[16] Under more forcing conditions, 8-*iso*propyltotar-13(14)-en-7-one (XX) was obtained. [The nomenclature in this paper is based[17] on the hydrocarbons podo-carpane (XXI) and totarane (XXII)].

Treatment of the mixture with *N*-bromosuccinimide in boiling carbon tetrachloride gave a bromo-ketone, or a mixture of bromo-ketones, which, on dehydrobromination in boiling γ-collidine, gave (±)-totarol (I), together with some ketonic material (largely XVIII). These were separated by careful chromatography on alumina, (±)-totarol being obtained as a colourless glass. The ultraviolet spectrum, and the infrared spectrum measured in carbon disulphide solution, were identical with those of (+)-totarol, a specimen of which was kindly provided by Dr. D. A. Peak of Boots Pure Drug Co. Ltd. The benzoates of synthetic and of (+)-totarol were also spectroscopically indistinguishable in both the ultraviolet and the infrared region.

EXPERIMENTAL

2-(β-m-*Methoxyphenylacryloyl*)-1 : 3 : 3-*trimethyl*cyclo*hexene (III).—2-Acetyl-1 : 3 : 3-tri-methyl*cyclo*hexene (3·42 g.), *m*-methoxybenzaldehyde (2·72 g.), and potassium hydroxide (0·56 g.) were heated under reflux for 30 min. in ethanol (30 c.c.). The mixture was acidified with acetic acid and most of the ethanol was removed under reduced pressure. The product was extracted with ether and washed with aqueous sodium carbonate and brine, dried, and distilled. The fraction of b. p. 165—175°/0·1 mm. was redistilled, to give the *acyl*cyclo*hexene (3·49 g.), b. p. 166—169°/0·1 mm. (Found: C, 79·9; H, 8·4. $C_{19}H_{24}O_2$ requires C, 80·3; H, 8·4%).

2-(β-m-*Methoxyphenylpropionyl*)-1 : 3 : 3-*trimethyl*cyclo*hexene (IV).—The above ketone (3·25 g.) in ethanol (40 c.c.) was hydrogenated under atmospheric pressure over Raney nickel. The reduction stopped after the uptake of 1·1 mols. of hydrogen. The filtered solution when distilled gave the *product* as a pale yellow liquid (2·75 g.), b. p. 185—190°/0·1 mm. (bath-temp.) (Found: C, 79·6; H, 9·0. $C_{19}H_{26}O_2$ requires C, 79·7; H, 9·1%).

[13] Hosking, *Ber.*, 1936, **69**, 780.
[14] Jeger, personal communication.
[15] Conia, *Bull. Soc. chim. France*, 1954, 690, 943.
[16] Woodward, *J. Amer. Chem. Soc.*, 1941, **63**, 1123; 1942, **64**, 72, 76.
[17] Klyne, *J.*, 1953, 3072.

Attempted Cyclisation of 2-(β-m-*Methoxyphenylpropionyl*)-1 : 3 : 3-*trimethylcyclohexene.*—
(*A*) The ketone (5·72 g.) in nitrobenzene (50 c.c.) was saturated with dry hydrogen chloride.
To the stirred solution was added finely powdered aluminium chloride (8·1 g.) and the stirring
was continued for 20 hr. at room temperature. The mixture was poured on ice, and the nitro-
benzene removed by steam-distillation. The residue was isolated with ether and distilled, to
give 5-methoxyindan-1-one (VII) (1·01 g.), b. p. 145—150°/0·2 mm., which crystallised.
Crystallisation from light petroleum and then benzene gave needles, m. p. 108° (Found: C, 73·7;
H, 6·2. Calc. for $C_{10}H_{10}O_2$: C, 74·1; H, 6·2%) (semicarbazone, m. p. 237—238°) (Brandt
and Horn,[18] and Ingold and Piggott [19] give m. p. 108°, and semicarbazone, m. p. 239°). The
infrared spectrum had bands (μ) at 5·91 s, 7·98 s, 9·68 s, 12·35 m, and 14·1 m. The ultraviolet
spectrum had bands at 266 ($\varepsilon_{max.}$ 2120) and 287 mμ ($\varepsilon_{max.}$ 1540).

(*B*) 2-(β-*m*-Methoxyphenylpropionyl)-1 : 3 : 3-trimethyl*cyclo*hexene (5·01 g.) was stirred
with 90% phosphoric acid (50 c.c.) at 140—150° for 5 hr. under nitrogen. The pale brown
mixture was poured on ice, and the product was extracted with ether, washed with sodium
carbonate solution and water, and dried. Evaporation gave 5-methoxyindan-1-one (VII)
(2·01 g.).

(*C*) The acyl*cyclo*hexene (10 g.) in pure dry benzene (120 c.c.) was added slowly, with stirring,
to a boiling suspension of aluminium chloride (18 g.) in benzene (100 c.c.) through which a slow
stream of dry hydrogen chloride was passed. The addition was complete in 1 hr., and stirring
and treatment with hydrogen chloride were continued for 1 hr. longer. Stirring was continued
for a further 2 hr. and the mixture was then poured on 2N-hydrochloric acid and ice. Isolation
with ether followed by distillation gave three fractions: (*a*), b. p. 75—100°/0·2 mm., was
redistilled to give 1 : 3 : 3-*trimethyl-1-phenylcyclohexane* (VIII) (0·2 g.), b. p. 78—83°/0·2 mm.
(Found: C, 89·6; H, 10·1. $C_{15}H_{22}$ requires C, 89·1; H, 10·9%), whose infrared spectrum
showed no carbonyl or ether absorption and had strong bands at 13·35 μ and 14·38 μ, the
ultraviolet spectrum having a broad band system at *ca.* 260 mμ with peaks at 252 ($\varepsilon_{max.}$ 278),
257·5 ($\varepsilon_{max.}$ 283), 263·5 ($\varepsilon_{max.}$ 260), 267 ($\varepsilon_{max.}$ 238), and 282 mμ ($\varepsilon_{max.}$ 184). *Fraction* (*b*) (3·3 g.),
b. p. 175—185°/0·2 mm., was redistilled, to give unchanged 2-(β-*m*-methoxyphenylpropionyl)-
1 : 3 : 3-trimethyl*cyclo*hexene (IV), b. p. 175—180°/0·2 mm. *Fraction* (*c*) (2·2 g.), b. p. 195—
205°/0·2 mm., was redistilled to give 2-(β-m-*methoxyphenylpropionyl*)-1 : 3 : 3-*trimethyl-1-
phenylcyclohexane* (IX), b. p. 195—200°/0·2 mm. (Found: C, 82·1; H, 8·9. $C_{25}H_{32}O_2$ requires
C, 82·4; H, 8·9%), whose infrared spectrum had bands at 5·87 s, 7·98 s, 9·68 s, 12·85 m, 13·25 s,
and 14·35 sμ, the ultraviolet spectrum having bands at 215 ($\varepsilon_{max.}$ 13,100), 273 ($\varepsilon_{max.}$ 3460), and
280 mμ ($\varepsilon_{max.}$ 3400).

2 : 2 : 6-*Trimethyl-1-phenylethynylcyclohexanol* (XIII; R = H).—Phenylacetylene (2·44 g.)
in anhydrous ether (30 c.c.) was added dropwise with stirring to a solution of potassamide (from
1·0 g. of potassium) in liquid ammonia (100 c.c.). After 10 min., 2 : 2 : 6-trimethyl*cyclo*-
hexanone (3·4 g.) in anhydrous ether (30 c.c.) was added dropwise and stirring was continued
for 2 hr. Water was added and the product was extracted with ether, washed with brine,
and distilled. 2 : 2 : 6-*Trimethyl-1-phenylethynylcyclohexanol* (2·47 g.) was collected at
153—156°/0·15 mm. (Found: C, 84·3; H, 9·3. $C_{17}H_{22}O$ requires C, 84·3; H, 9·1%).

2 : 6 : 6-*Trimethyl-1-phenethylcyclohexanol* (XIV; R = H).—2 : 2 : 6-Trimethyl-1-phenyl-
ethynyl*cyclo*hexanol (2·45 g.) in ethyl acetate (70 c.c.) was hydrogenated over 5% palladised
charcoal (0·5 g.) at 1 atm. and room temperature. When the uptake of hydrogen had ceased,
the solution was filtered and distilled. 2 : 6 : 6-*Trimethyl-1-phenethylcyclohexanol* was obtained
as a colourless oil (2·40 g.), b. p. 172—177°/0·1 mm. (bath-temp.) (Found: C, 82·3; H, 10·4.
$C_{17}H_{26}O$ requires C, 82·9; H, 10·6%).

1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-*Octahydro*-1 : 1 : 12-*trimethylphenanthrene* (XV; R = H).—
2 : 2 : 6-Trimethyl-1-phenethyl*cyclo*hexanol (2·3 g.) was stirred with 90% phosphoric acid
(20 c.c.) and phosphoric oxide (25 g.) under dry nitrogen for 45 min. at 95°, then cooled, poured
into water (200 c.c.), and extracted with ether. The extract was washed with brine, dried,
and distilled. 1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-*Octahydro*-1 : 1 : 12-*trimethylphenanthrene* (1·6 g.)
obtained had b. p. 108—110°/0·05 mm. (Found: C, 89·0; H, 10·5. $C_{17}H_{24}$ requires C, 89·5;
H, 10·5%).

1-(m-*Methoxyphenylethynyl*)-2 : 2 : 6-*trimethylcyclohexanol* (XIII; R = MeO).—*m*-Methoxy-
phenylacetylene (9·8 g.) in anhydrous ether (90 c.c.) was slowly added with stirring to a solution

---

[18] Brandt and Horn, *J. prakt. Chem.*, 1927, **115**, 351.
[19] Ingold and Piggott, *J.*, 1923, 1469.

of potassamide (from 3·75 g. of potassium) in liquid ammonia (450 c.c.). After 10 min., 2 : 2 : 6-trimethyl*cyclo*hexanone (9·8 g.) in dry ether (90 c.c.) was added dropwise and stirring was continued for 1 hr. The mixture was worked up in the usual way, to give 1-(m-*methoxyphenylethynyl*)-2 : 2 : 6-trimethyl*cyclo*hexanol (15·75 g.), b. p. 180—185°/0·1 mm. (Found: C, 79·0; H, 8·8. $C_{18}H_{24}O_2$ requires C, 79·4; H, 8·8%).

1-(m-*Methoxyphenethyl*)-2 : 2 : 6-*trimethylcyclohexanol* (XIV; R = MeO).—1-(*m*-Methoxyphenylethynyl)-2 : 2 : 6-trimethyl*cyclo*hexanol (15·7 g.) was reduced as above, to give 1-(m-*methoxyphenethyl*)-2 : 2 : 6-*trimethyl*cyclohexanol (15·5 g.), b. p. 210—212°/0·15 mm. (bathtemp.) (Found: C, 78·8; H, 10·0. $C_{18}H_{28}O_2$ requires C, 78·3; H, 10·2%).

trans-1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-*Octahydro-7-methoxy*-1 : 1 : 12-*trimethylphenanthrene* (XV; R = OMe).—1-(3-Methoxyphenethyl)-2 : 2 : 6-trimethyl*cyclo*hexanol (10·0 g.) was stirred under nitrogen with syrupy phosphoric acid (120 c.c.) and phosphoric oxide (150 g.) for 45 min. at 85°. The mixture was worked up in the usual way, to give trans-1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-*octahydro-7-methoxy*-1 : 1 : 12-*trimethylphenanthrene* (7·93 g.) (a pale violet fluorescence), b. p. 155—160°/0·1 mm., needles, m. p. 52—55° (Found: C, 83·7; H, 10·1. $C_{18}H_{26}O$ requires C, 83·7; H, 10·1%).

Chromatography of 0·5 g. of the product on active alumina (60 g.) gave only one isolatable product. The m. p.s and infrared spectra of the fractions collected during this chromatography were identical.

*Podocarp-*8(14)-(XVI) *and podocarp*-13(14)-*en-*7-*one* (XVII).—trans-1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-Octahydro-7-methoxy-1 : 1 : 12-trimethylphenanthrene (XV; R = OMe) (7·93 g.) in anhydrous ether (400 c.c.) was added to liquid ammonia (1 l.) and treated with lithium metal (3·5 g.; 15 atoms per mole) in small pieces with stirring. Stirring was continued for 10 min. and then ethanol (50 c.c.) was added dropwise during 20 min. When the reaction was complete and the ammonia had evaporated, the mixture was diluted with water (500 c.c.), and the product isolated with ether. A colourless oil (7·02 g.) was obtained, the infrared spectrum of which showed only very weak bands attributable to starting material.

(*A*) The crude reduction product (3·5 g.) was heated to 60° for 30 min. with ethanol (150 c.c.) and 5N-hydrochloric acid (120 c.c.), then poured into ice-water and worked up in the usual way, to give a pale yellow oil (2·7 g.). This was chromatographed on a column of alumina (250 g.) which had been deactivated with 5% w/v of 10% aqueous acetic acid. Elution with light petroleum (b. p. 40—60°) gave unchanged trans-1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-octahydro-7-methoxy-1 : 1 : 12-trimethylphenanthrene (720 mg.). Further elution with 10% benzene in light petroleum gave successively podocarp-13(14)- (XVII) (780 mg.) and *podocarp-*8(14)-*en-*7-*one* (XVI) (897 mg.). The latter rapidly solidified and recrystallisation from light petroleum gave the pure αβ-unsaturated ketone, m. p. 89—90° (Found: C, 82·7; H, 10·2. $C_{17}H_{26}O$ requires C, 82·9; H, 10·6%), $\lambda_{max.}$ 241·5 mμ (ε 16,150). The semicarbazone had m. p. 213—215° (decomp.).

(*B*) The crude reduction product (3·5 g.) in ethanol (200 c.c.) was treated with oxalic acid (7·5 g.) and water (10 c.c.) at 25° for 40 min., then poured into water (500 c.c.) and worked up in the usual manner, to give a colourless oil which was chromatographed on deactivated alumina (350 g.). Elution with light petroleum gave unchanged trans-1 : 2 : 3 : 4 : 9 : 10 : 11 : 12-octahydro-7-methoxy-1 : 1 : 12-trimethylphenanthrene (700 mg.). Further elution with 10% benzene in light petroleum gave *podocarp-*13(14)-*en-*7-*one* (XVII) (2·65 g.) which separated from light petroleum in crystals, m. p. 101—103° (Found: C, 82·7; H, 11·0%).

*Isomerisation of Podocarp-*13(14)-*en-*7-*one* (XVII).—The ketone (530 mg.) was heated at 90° with ethanol (20 c.c.) and 5N-hydrochloric acid (15 c.c.) for 30 min. The mixture was worked up in the usual way. The infrared spectrum of the crude product indicated the presence of both starting material and the αβ-unsaturated ketone (XVI). Chromatography on deactivated alumina (30 g.) gave unchanged podocarp-13(14)- (170 mg.) and podocarp-8(14)-en-7-one (195 mg.).

*Proof of Identity of Synthetic Podocarp-*8(14)-*en-*7-*one with the* (+)-*Compound.*—The infrared spectra of (+)- and (±)-podocarp-8(14)-en-7-one semicarbazone in Nujol mull were identical apart from the following slight differences: (+)-isomer, 13·15, 12·25, 9·21, 7·55 μ; (±)-isomer, 13·18, 12·27, 9·16, 7·53 μ. The (+)-semicarbazone (16·1 mg.) was heated under reflux for 20 min. with 2N-hydrochloric acid (5 c.c.) and ethanol (1 c.c.). The mixture was diluted with water, and the product was isolated with ether. The pale yellow oil (11·7 mg.) had an infrared spectrum which indicated some isomerisation to the 13(14)-isomer (bands at 5·8 and 5·98 μ).

The mixture was chromatographed on deactivated alumina (1·5 g.). Elution with 1 : 1 benzene–light petroleum gave (+)-podocarp-8(14)-en-7-one (2·0 mg.) which slowly crystallised. The infrared spectrum of this ketone, in CS_2, proved identical in all respects with that of the synthetic material measured under the same conditions.

Totar-8(14)- (XVIII) *and Totar*-13(14)-*en*-7-*one* (XIX).—(*A*) Podocarp-8(14)-en-7-one (XVI) (415 mg.) in *iso*propyl bromide (8 c.c.; 50 mol.) was treated with a M-solution of sodium *tert.*-amyloxide in dry benzene (15 c.c.; 10 mol.), under dry nitrogen. The mixture was heated under reflux for $3\frac{1}{2}$ hr., cooled, and shaken with 2N-hydrochloric acid (25 c.c.). The product was isolated with ether and chromatographed on deactivated alumina (40 g.). Elution with benzene gave a pale yellow viscous oil (175 mg.), b. p. 155—160°/0·05 mm. (bath-temp.) (Found: C, 83·5; H, 11·0. $C_{20}H_{32}O$ requires C, 83·3; H, 11·1%). The infrared spectrum had bands at 5·85 and 6·0 μ, showing that both totar-8(14)- and totar-13(14)-en-7-one were present. Very little change in the composition of the mixture was achieved by chromatography on alumina. The ultraviolet spectrum had a band at 251 mμ (ε 6900).

(*B*) A mixture of podocarp-8(14)- and -13(14)-en-7-one (760 mg.) in *iso*propyl iodide (7 c.c.; 40 mol.) was treated with M-sodium *tert.*-amyloxide in dry benzene (20 c.c.; 10 mol.) under dry nitrogen and heated under reflux for $2\frac{1}{2}$ hr. A deep red colour was produced on warming which gradually disappeared as sodium iodide was precipitated. After acidification with 2N-sulphuric acid (10 c.c.) the product, a yellow oil (705 mg.), was isolated with ether and chromatographed on deactivated alumina (70 g.). Elution with light petroleum gave 8-iso*propyltotar*-13(14)-*en*-7-*one* (XX) (267 mg.), b. p. 165—170°/0·1 mm. (bath-temp.) (Found: as 83·9; H, 11·3. $C_{23}H_{38}O$ requires C, 83·6; H, 11·5%). Further elution with 1 : 1 benzene–light petroleum gave a mixture of totaren-7-ones (202 mg.).

(*C*) Podocarp-13(14)-en-7-one (680 mg.) in *iso*propyl iodide (2·5 c.c.; 15 mol.) was treated C, above, with M-sodium *tert.*-amyloxide (7·5 c.c.; 5 mol.), refluxing being continued for 1 hr. The product was a pale yellow oil (690 mg.) which, on distillation, gave a mixture of totaren-7-ones (Found: C, 82·9; H, 11·3%).

(±)-*Totarol* (I).—The synthetic mixture of totaren-7-ones (420 mg.) and freshly prepared *N*-bromosuccinimide (290 mg.; 1·1 mol.) were heated together under reflux in dry carbon tetrachloride for 30 min., then cooled, filtered, washed with 10% sodium carbonate solution, and evaporated. A pale yellow viscous oil was obtained which when heated to 100° in a vacuum lost some hydrogen bromide. A glass (400 mg.) remained which was heated under reflux with redistilled γ-collidine (15 c.c.) for $2\frac{1}{2}$ hr. The bulk of the γ-collidine was removed in a vacuum, 5N-hydrochloric acid (15 c.c.) added, and the product isolated with ether. The residual clear brown glass (380 mg.), the infrared spectrum of which showed, in addition to those bands expected for (±)-totarol, a weak band at 5·85 μ and a moderately intense band at 6·0 μ, was chromatographed on deactivated alumina (40 g.). Elution with light petroleum gave 118 mg. of ketone. Further elution with 1 : 1 benzene–light petroleum gave a pale yellow glass (182 mg.) the infrared spectrum of which showed that very little ketone was present. The fractions containing least ketonic material (83 mg.) were rechromatographed on active alumina (10 g.). Elution with 1 : 1 benzene–light petroleum gave a mixture of totaren-7-ones (15·8 mg.). Further elution with benzene gave (±)-*totarol* (35·3 mg.), b. p. 170—175° (bath-temp.)/0·2 mm. (Found: C, 84·4; H, 10·4. $C_{20}H_{30}O$ requires C, 83·9; H, 10·5%), whose infrared spectrum, in CS_2, was identical with that of (+)-totarol. The ultraviolet spectrum had a band at 278 (ε 1970) and a shoulder at 285 mμ (ε 1910). (+)-Totarol had a band at 278 (ε 1980) and a shoulder at 285 mμ (ε 1915). (±)-*Totaryl benzoate* was a glass, b. p. 145—150° (bath-temp.)/2 × 10⁻⁵ mm. (Found: C, 83·5; H, 9·0. $C_{27}H_{34}O$ requires C, 83·1; H, 8·9%), whose infrared spectrum in CS_2 was identical with that of (+)-totaryl benzoate (m. p. 144—145°). The ultraviolet spectra of the racemic and the dextrorotatory materials were identical ($\lambda_{max.}$ 220 mμ, ε 21,000; 228 mμ, ε 20,000; shoulder at 265 mμ, ε 3300).