A Stereospecific Synthetic Route to Campherenone, Campherenol, Epicampherenone, β-Santalene, Epi-β-santalene, Ylangocamphor, Copacamphor, Sativene, and Copacamphene

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A simple and efficient synthetic route to either enantiomeric form of campherenone and epicampherenone [the epimeric 1,7-dimethyl-7-(4-methylpent-3-enyl)norbornan-2-ones], β-santalene and epi-β-santalene [2-methyl-3-methylene-2-(4-methylpent-3-enyl)norbornanes], and the perhydro-1,4-methanoindene derivatives copacamphor, copacamphene, ylangocamphor, and sativene is described. The simplicity of the synthetic route is due to the application of a general synthetic plan and the development of a new process for effecting direct 8-substitution of camphor.

We have described previously [1-3] a general synthetic scheme (Scheme 1) for a group of sesquiterpenes which, individually, have been prime targets for the synthetic endeavours of many workers. The success of our strategy was illustrated by efficient synthetic routes to campherenone, epicampherenone, β-santalene, epi-β-santalene, α-santalene, copacamphor, ylangocamphor, and sativen. In addition it is hoped that current studies in our laboratory will result in extension of this list to include the remaining compounds originally considered within the scope of our synthetic scheme (Scheme 1).

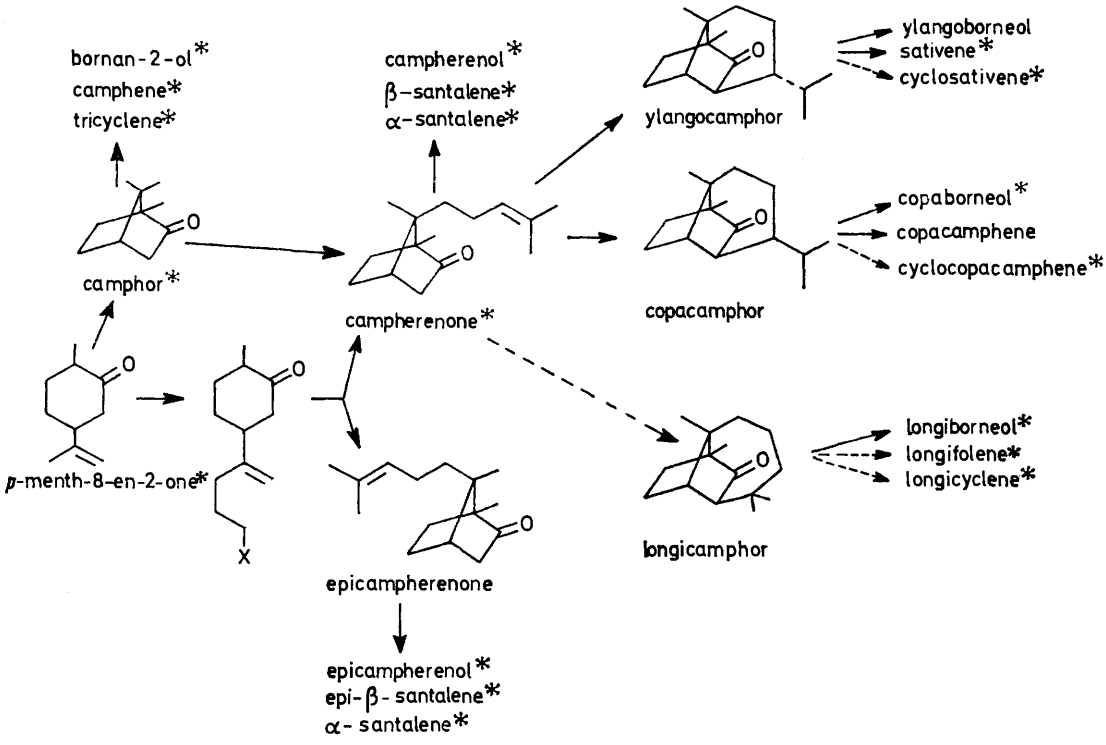
In spite of the fact that we chose (+)-*p*-menth-8-en-2-one (dihydrocarvone) as our starting material, the bicyclic and tricyclic sesquiterpenes which we have synthesized (unbroken arrows, Scheme 1) were obtained as racemates. To place our scheme on an absolute configurational basis and increase its potential in taxonomic and biosynthetic areas we have devised an alternative synthesis which can provide us with either enantiomer of each of these compounds in an efficient manner. Our new synthetic route is based on a simple conversion of (+)- or (−)-camphor into (+)- or (−)-campherenone. As indicated in Scheme 1, campherenone occupies a key position in our general synthetic strategy and its configurational integrity is maintained during subsequent transformations into the other sesquiterpenes listed in the title.

As a means of converting camphor into campherenone we considered the well known isoprenylation process

[1] G. L. Hodgson, D. F. MacSweeney, and T. Money, *J.C.S. Perkin I*, 1973, 2113.

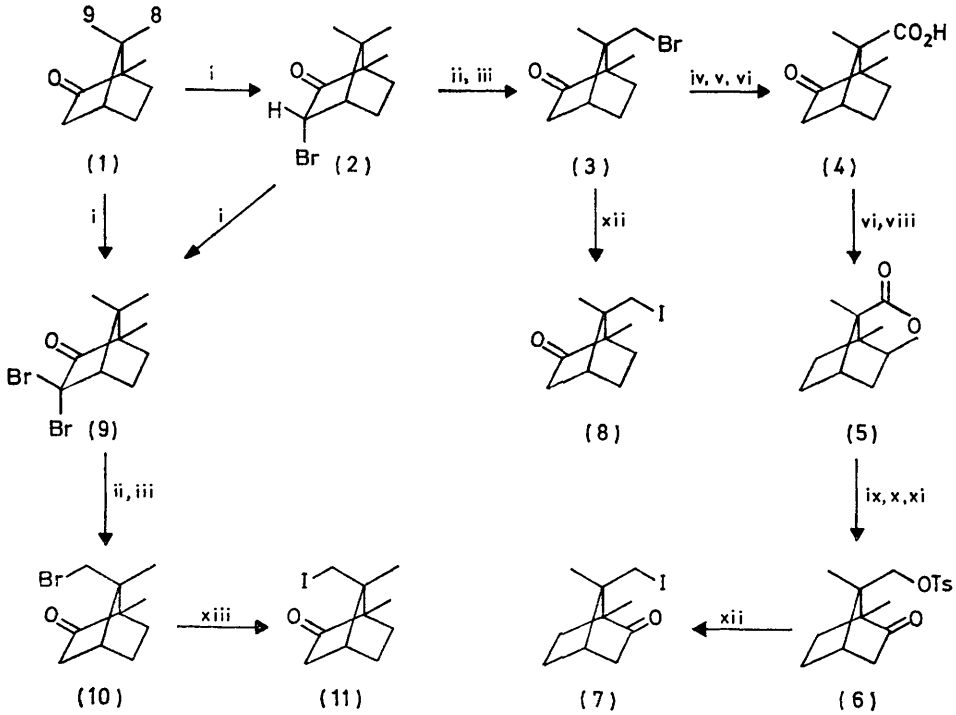
[2] G. L. Hodgson, D. F. MacSweeney, and T. Money, (*a*) *Chem. Comm.*, 1971, 766; (*b*) *Tetrahedron Letters*, 1972, 3683.

[3] T. Money, *Progr. Org. Chem.*, 1973, **8**, 29.



SCHEME 1

* Naturally occurring compound. Broken arrows denote incomplete sequences.

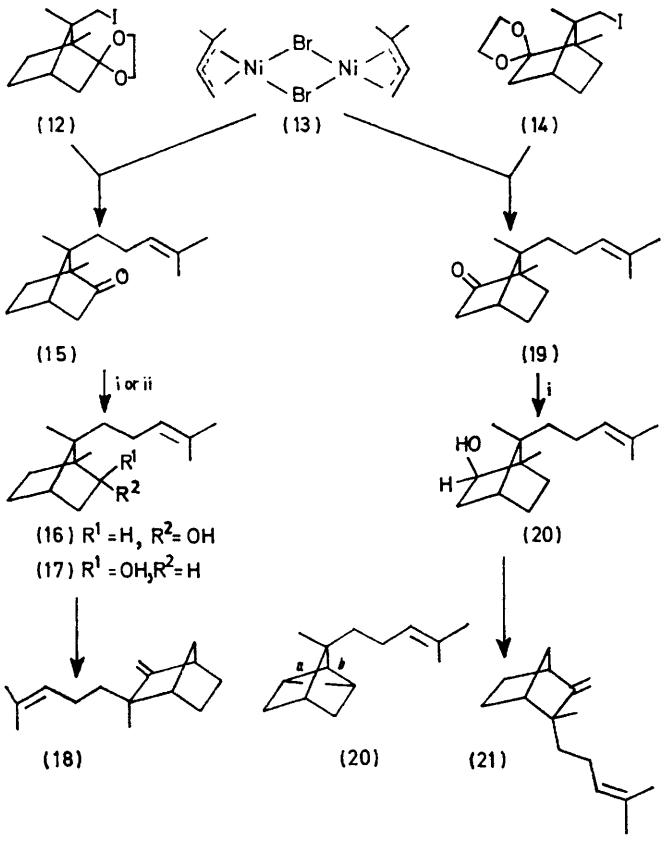


SCHEME 2 Reagents: i, Br; ii, Br_2–$ClSO_3H$; iii, Zn–HBr; iv, KOAc–HOAc; v, KOH–EtOH; vi, CrO_3–$MnSO_4$–H^+; vii, $NaBH_4$; viii, $CF_3{\cdot}CO_2H$–H^+–Br_2; ix, $LiAlH_4$; x, TsCl–C_5H_5N; xi, CrO_3–C_5H_5N; xii, NaI–Me_2SO; xiii, NaI–$PO(NMe_2)_3$.

based on the use of the complex (13) derived from 3-methylbut-2-enyl bromide and tetracarbonylnickel.[4] The obvious substrate for reaction with this nucleophilic reagent was optically active 8-bromo- or 8-iodo-camphor, and in our initial investigations [5] (+)-camphor (1) was converted into (−)-8-iodocamphor (7) by a twelve-step route (Scheme 2) based on a combination of known reaction sequences.[6] The desirability of a more efficient and direct route to this important derivative of camphor focused our attention on the general problems associated with this objective. As a result of applying mechanistic arguments which we have described elsewhere [7] we arrived at a simple solution to this problem. This required the use of a 3-*exo*-substituted camphor as starting material; bearing in mind that the substituent had to be removed subsequently, we therefore synthesized (+)-3,3-dibromocamphor (9) * [in 95% yield from commercially available (+)-3-bromocamphor (2)] and subjected it to conditions (Br_2–$ClSO_3H$) usually employed to brominate camphor at the 9-position.[9] Treatment of the crude product with zinc and hydrobromic acid provided (+)-8-bromocamphor (10), which was converted into (+)-8-iodocamphor (11) by refluxing with sodium iodide in hexamethylphosphoramide for 72 h. The success of our 8-bromination reaction thus enabled us to avoid a tedious multi-step sequence (Scheme 2) and provided us with the possibility of achieving a simple stereospecific conversion of camphor into the sesquiterpenes included within the scope of our general synthetic plan.

In the event, treatment of the acetal iodide (12), derived from (−)-8-iodocamphor (7), with the π-allylnickel complex (13) derived from 3-methylbut-2-enyl bromide, followed by hydrolysis, provided (−)-campherenone (15) in *ca.* 50% overall yield from (−)-camphor. Since the absolute configuration of the initial 8-bromo- and 8-iodo-camphor had been confirmed by *X*-ray analysis [10] and hydrogenolysis to (−)-camphor, our successful synthesis of (−)-campherenone also established its absolute configuration. Subsequent reduction of (−)-campherenone (15) with sodium–propan-1-ol and with lithium hydridotrimethoxyaluminate provided (−)-campherenol (16) and (+)-isocampherenol (17), respectively. The latter, on heating with toluene-*p*-sulphonyl chloride in pyridine [1] was converted into (−)-β-santalene (18) in 70% yield. In a similar fashion (+)-epicampherenone (19) was synthesized from (−)-9-iodocamphor ethylene acetal (14) and subsequently transformed into (+)-epi-β-santalene (21).

In a previous report we postulated that a biosynthetic relationship could exist among (−)-campherenone (15), (−)-campherenol (16), (−)-β-santalene (18),† and (+)-α-santalene (22); the co-occurrence [11] of these compounds



SCHEME 3 Reagents: i, $LiAl(OMe)_3H$; ii, Na–PrOH

in *Cinnamomum camphora* may be cited in support of this view. At that time, however, the absolute configurations assigned to (−)-campherenone and (−)-campherenol, on the basis of c.d. data, were enantiomeric to those shown. Thus we were compelled to conclude, temporarily, that campherenone and campherenol were not biosynthetically related to the santalenes (α and β) *or* that the assignments of absolute configuration to the former compounds were in error. The latter conclusion has been validated by the synthetic results described above although we are still unable to explain the discrepancies between our c.d. and o.r.d. data and those quoted in the literature [11] (*cf.* Experimental section).

The co-occurrence of (+)-α-santalene (22), (−)-β-

* This compound can also be obtained when (+)-camphor (1) is treated directly with bromine.[8]

† We have assumed that the β-santalene which occurs in *C. camphora* is laevorotatory. In the original report [11] the specific rotation was not given.

[4] E. J. Corey and M. F. Semmelhack, *J. Amer. Chem. Soc.*, 1967, **89**, 2755; *cf.* K. Sato, S. Inoue, S. Ota, and Y. Fujita, *J. Org. Chem.*, 1972, **37**, 462.

[5] G. L. Hodgson, D. F. MacSweeney, and T. Money, *J.C.S. Chem. Comm.*, 1973, 235.

[6] (*a*) E. J. Corey, M. Ohno, S. W. Chow, and R. A. Scherrer, *J. Amer. Chem. Soc.*, 1959, **81**, 6305; (*b*) O. R. Rodig and R. J. Sysko, *J. Org. Chem.*, 1971, **36**, 2324.

[7] C. R. Eck, R. W. Mills, and T. Money, *J.C.S. Chem. Comm.*, 1973, 911.

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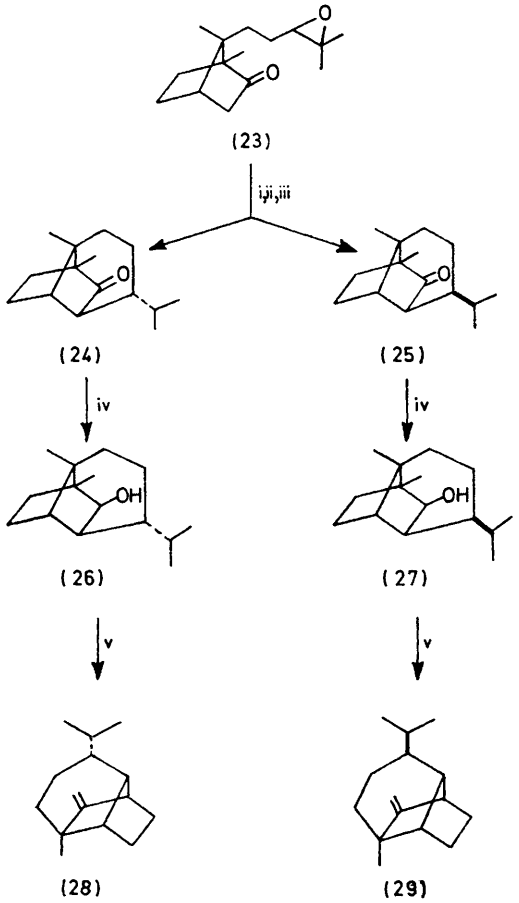
[9] (*a*) E. J. Corey, S. W. Chow, and R. A. Scherrer, *J. Amer. Chem. Soc.*, 1957, **79**, 5773; (*b*) W. L. Meyer, A. P. Lobo, and R. N. McCarty, *J. Org. Chem.*, 1967, **32**, 1754.

[10] C. A. Bear, C. R. Eck, R. W. Mills, T. Money, and J. Trotter, in preparation.

[11] H. Hikino, N. Suzuki, and T. Takemoto, *Chem. and Pharm. Bull (Japan)*, 1971, **19**, 87.

santalene (18), and (+)-epi-β-santalene (21)* in *Santalum album* [12] poses a question regarding the biosynthesis of the latter compound. The absolute configuration of (+)-epi-β-santalene (21) established by synthesis (see above and ref. 4) does not necessarily preclude a biosynthetic connection between this compound and (−)-β-santalene (18) since cleavage of bonds *a* and *b* in (+)-α-santalene (22) could account for their formation. Alternatively one could envisage a biosynthetic route involving dehydration of (+)-isoepicampherenol (20). We have recently been informed [13] that the latter compound or its enantiomer has been isolated from *Verbesina rupestris* and it would be significant if (+)-epi-β-santalene (21) occurred in the same source.

The synthesis of either enantiomer of campherenone



SCHEME 4

Reagents: i, $KOBu^t$–$HOBu^t$; ii, $SOCl_2$–C_5H_5N; iii, H_2–Pt; iv, $LiAlH_4$; v, $MeSO_2Cl$–C_5H_5N.

from the appropriate enantiomer of camphor is a comparatively simple and efficient process, and the subsequent application of the synthetic methodology described for the racemic series [1] provides us with a synthetic route to (+)-ylangocamphor (24), (+)-copacamphor (25), (−)-sativene (28), and (−)-copacamphene (29) or the enantiomeric set. These further transformations of campherenone (15) have been simplified to the point where ylangocamphor (24) and copacamphor (25) can be obtained in four steps without purification of intermediates. The final separation of ylangocamphor (24) and copacamphor (25) can be achieved by column chromatography.†

Of our initial general objectives only the conversion of campherenone into the longicamphor–longifolene group (*cf.* Scheme 1) and the synthesis of tetracyclic analogues of α-santalene (22) (*i.e.* cyclosativene, cyclocopacamphene, and longicyclene) remain to be achieved. These aspects of our general scheme and its extension to more highly oxygenated derivatives of parent structures are under investigation.

EXPERIMENTAL

For general procedures see ref. 16.

(+)-9-*Iodocamphor* (8).—(+)-9-Bromocamphor (3) [9] (200 mg) was treated with sodium iodide (820 mg) in hexamethylphosphoramide (3 ml) at 100° under nitrogen for 4 days. After cooling and diluting with water the mixture was extracted with petroleum and the extract washed with sodium disulphite solution. Work-up provided a white solid (230 mg, 95%). Crystallization from petroleum yielded (+)-9-iodocamphor (8), m.p. 62—63°; $[\alpha]_D$ +144·5° (*c* 4·52 in $CHCl_3$); $\nu_{max.}$ (CCl_4) 1750 cm^{-1}; τ (CCl_4) 9·05 (3H, s), 9·00 (3H, d, *J* 1 Hz), and 6·82 (d) and 6·42 (q) (2H, J_{AB} 10, J_{AX} 1, J_{BX} 0 Hz).

(−)-9-*Iodocamphor Ethylene Acetal* (14).—*Method A*.[5] (+)-9-Bromocamphor (3) [9] (5 g) was refluxed in ethylene glycol (8 ml) with toluene-*p*-sulphonic acid (500 mg) for 36 h. Work-up gave (+)-9-bromocamphor ethylene acetal (80%), b.p. 64—65° at 0·06 mmHg; $[\alpha]_D^{24}$ +1·2° (*c* 7·46 in $CHCl_3$); τ (CCl_4) 9·20 (3H, s), 8·83 (3H, d, *J* 1·5 Hz), 6·90 and 6·47 (2H, d, and dq, J_{AB} 10·5, J_{AX} 1·5, J_{BX} 0 Hz), and 6·20 (4H, m); *m/e* 276 (1·3%, M^+), 274 (1·3, M^+), 195 (100), 109 (44·2), 95 (37·7), 87 (56·8), and 41 (21·4).

A solution of the acetal (4·4 g) in dry dimethyl sulphoxide (40 ml) was treated with sodium iodide (15 g; dried over P_2O_5 for 24 h at 1 mmHg) in the presence of anhydrous calcium carbonate (5 g) for 3 days at 110° under nitrogen. Extraction with petroleum (3 × 100 ml) followed by removal of the solvent provided a product which was shown by g.l.c. (3% SE 30; 175°) to be a *ca.* 1 : 4 mixture of starting material (t_R 4·2 min) and (−)-9-iodocamphor ethylene acetal (14). Distillation provided pure (−)-9-iodocamphor ethylene acetal (14), b.p. 75° at 0·05 mmHg; $[\alpha]_D^{29}$ −2·2° (*c* 5·00 in $CHCl_3$); τ (CCl_4) 9·19 (3H, s), 8·85 (3H, d, *J* 1·5 Hz), 7·08 and 6·62 (2H, d and dq, J_{AB} 9·5, J_{AX} 1·5, J_{BX} 0 Hz), and 6·11 (4H, m).

Method B. The title compound can also be synthesized by similar treatment of (+)-9-iodocamphor (8) with ethylene glycol and toluene-*p*-sulphonic acid.

* The isolation of pure epi-β-santalene from *S. album* involves painstaking chromatographic operations [1] and the absence of a recorded specific rotation prior to our work reflects this difficulty.

† Elegant stereoselective syntheses of copacamphor, copacamphene, and ylangocamphor have been reported by Piers and his co-workers.[14,15]

[12] E. J. Corey, R. Hartmann, and P. A. Vatakencherry, *J. Amer. Chem. Soc.*, 1962, **84**, 2611.

[13] Professor W. R. Chan, University of the West Indies, personal communication.

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[15] E. Piers, R. W. Britton, R. J. Keziere, and R. D. Smillie, *Canad. J. Chem.*, 1971, **49**, (*a*), p. 2620; (*b*) p. 2623.

[16] J. C. Fairlie, G. L. Hodgson, and T. Money, *J.C.S. Perkin I*, 1973, 2109.

(+)-*Epicampherenone* [1,7-*Dimethyl*-7-(4-*methylpent*-3-*enyl*)*norbornan*-2-*one*)] (19).—A solution of tetracarbonylnickel (6 ml) and 3-methylbut-2-enyl bromide (3 ml) in dry benzene (20 ml) was stirred for 2·5 h at 50° under nitrogen.[4] The solvent was removed under vacuum and dry dimethylformamide (20 ml) was added to dissolve the residue. To this solution was added (−)-9-iodocamphor ethylene acetal (14) (1·5 g) in dry dimethylformamide (5 ml) and the mixture was stirred at 55—60° for 14 h under nitrogen. More nickel complex (from 2 g of the bromide) was then added and the reaction was continued for 48 h. The mixture was then added to dimethyl sulphoxide and extracted with petroleum. Solvent removal followed by distillation and column chromatography over alumina (elution with petroleum–ether, 9 : 1) provided epicampherenone ethylene acetal (500 mg, *ca.* 40% *). Removal of the acetal function, as described previously,[1] produced (+)-epicampherenone (19), $[\alpha]_D^{27}$ +84·4° (*c* 4·88 in $CHCl_3$), $[\theta]_{203}$ −22,000° (*c* 0·0027 in MeCN), $[\theta]_{298}$ +14,000° (*c* 0·054 in MeCN), with g.l.c. and spectral (i.r., n.m.r., and mass) characteristics identical with those of the racemic compound.[1]

(+)-*Epi*-β-*santalene* [2-*Methyl*-3-*methylene*-2-(4-*methylpent*-3-*enyl*)*norbornane*] (21).—The procedure used was identical with that described for the racemic compound.[1] Reduction of (+)-epicampherenone (19) with lithium hydridotrimethoxyaluminate gave (+)-isoepicampherenol (20), $[\alpha]_D^{30}$ +7·0° (*c* 5·1 in $CHCl_3$), which was dehydrated to provide (+)-epi-β-santalene (21), $[\alpha]_D^{29}$ +26·9° (*c* 2·6 in $CHCl_3$) {lit.,[1] $[\alpha]_D^{29}$ +23·3° (*c* 4·12 in $CHCl_3$)}. The spectral characteristics of compounds (20) and (21) were identical with those recorded [1] for the racemic compounds.

(+)-8-*Iodocamphor* (11).—(+)-8-Bromocamphor (10) [7] (62·5 g, 0·27 mol) was treated with sodium iodide (262 g, 1·75 mol) in hexamethylphosphoramide (500 ml) at 100° under nitrogen for 4 days. After cooling and diluting with water the mixture was extracted with ether (4 × 200 ml) and the extract washed with sodium disulphite solution. Drying and evaporation provided a crude oil (45 g), which was shown by g.l.c. (3% SE 30; 160°) to be a mixture containing *ca.* 95% (+)-8-iodocamphor (11). For subsequent synthetic use the mixture was treated with ethylene glycol and toluene-*p*-sulphonic acid, and the resulting 8-iodocamphor ethylene acetal was purified by distillation. Subsequent hydrolysis (HCl–Me_2CO) followed by crystallization from petroleum provided (+)-8-iodocamphor (11), m.p. 38—40°, $[\alpha]_D^{23}$ +86° (*c* 1·1 in $CHCl_3$), having spectroscopic properties identical with those of the enantiomer (see later).

(−)-8-*Iodocamphor Ethylene Acetal* (12).—*Method A.* The development of the foregoing direct route makes the treatment of the appropriate enantiomer of 8-bromocamphor with sodium iodide in hexamethylphosphoramide the most convenient and efficient route to 8-iodocamphor.

Method B.[5] (+)-Camphor (1) was converted into the lactone (5) by the procedure of Corey *et al.*[6a] The subsequent transformation of the lactone (5) into (−)-8-iodocamphor (7) was carried out by the procedure developed by Rodig and Sysko [6b] for the corresponding racemic series. By this procedure (−)-8-iodocamphor (7) was obtained as a pale yellow oil, which crystallized with difficulty from petroleum (40—60°), m.p. 37—40°, $[\alpha]_D^{32}$ −92·1° (*c* 1·14 in $CHCl_3$); $\nu_{max.}$ 1740 and 1415 cm^{-1}; τ ($CDCl_3$) 9·05 (3H, s), 8·86 (3H, s), and 7·02 (2H, s); *m/e* 278 (71·1%, M^+), 151 (49·5), 109 (94·5), 107 (100), 81 (94·8), 55 (74·2), and 41 (75·2).

A mixture of (−)-8-iodocamphor (4·5 g) ethylene glycol (10 ml), toluene-*p*-sulphonic acid (500 mg), and benzene (50 ml) was refluxed for 72 h in a Dean–Stark apparatus. Work-up provided an oil (4·4 g) which, on distillation, gave a forerun containing starting material (10%) and a main fraction of (−)-8-*iodocamphor ethylene acetal* (12) (4·5 g, 86%); b.p. 76° at 0·03 mmHg; $[\alpha]_D^{34}$ −37·3° (*c* 5·12 in $CHCl_3$); τ (CCl_4) 9·21 (3H, s), 8·96 (3H, d, *J* 2 Hz), 7·07 (d) and 6·00 (m) (2H, J_{AB} 10·5, J_{BX} 2, J_{AX} 0 Hz), and 6·20 (4H, m); *m/e* 195 (82·3%, M^+ −127), 109 (95·0), 87 (100), 67 (60·0), 43 (50·0), and 41 (57·5) (Found: C, 44·7; H, 6·1; I, 39·25. $C_{12}H_{19}IO_2$ requires C, 44·75; H, 5·95; I, 39·4%).

(−)-*Campherenone* (15).—A solution of tetracarbonylnickel (6·5 ml) and redistilled 3-methylbut-2-enyl bromide (4·5 g, 3·5 ml, 30 mmol) in dry benzene (20 ml) was stirred for 2·5 h at 50° under nitrogen. After removal of the solvent under reduced pressure, dry dimethylformamide (20 ml) was added and the mixture stirred until the solid had dissolved.[4] A solution of (−)-8-iodocamphor ethylene acetal (12) (2 g, 6·22 mmol) in dry dimethylformamide (10 ml) was added and the mixture was stirred for 36 h at 60° under nitrogen, cooled, added to dimethyl sulphoxide (20 ml), and extracted with petroleum (4 × 40 ml). Work-up provided an oil (4·07 g) which on distillation yielded (+)-campherenone ethylene acetal (1·5 g), b.p. 74° at 0·06 mmHg, $[\alpha]_D^{32}$ +14·5° (*c* 4·98 in $CHCl_3$), having i.r. and n.m.r. spectra in complete agreement with those recorded for the racemic compound.[1] In most preparations the crude oil (4·07 g) was hydrolysed without further purification by treating a solution in acetone (40 ml) with 6N-hydrochloric acid (0·5 ml) for 16 h at room temperature. Distillation of the crude product provided (−)-campherenone (15) (1·36 g), b.p. 110—113° at 1 mmHg, which was purified further by column chromatography over alumina (elution with ether–petroleum, 1 : 1). T.l.c. and g.l.c. (3% SE 30; 150°) indicated that the final product was pure (−)-campherenone (15); $[\alpha]_D^{23}$ −30·6° (*c* 10·7 in $CHCl_3$), $[\alpha]_D^{27}$ −27° (*c* 10·03 in MeOH); $[\Delta\varepsilon]_{295}$(MeOH) −0·95°, $[\Delta\varepsilon]_{210}$(MeOH) +0·36°; $[\theta]_{295}$(MeOH) −3120° $[\theta]_{210}$(MeOH) +1195°; $[\phi]_{310}$ −2092°, $[\phi]_{295}$ 0, $[\phi]_{275}$ +1375 (*c* 1·58 in MeOH); {lit.,[10] $[\alpha]_D$ −33·0° (*c* 10·0 in $CHCl_3$); $[\theta]_{298}$(MeOH) +600°; $[\phi]_{308}$ +320, $[\phi]_{296}$ 0, $[\phi]_{274}$ −540 (*c* 0·11 in MeOH)}. The i.r. and n.m.r. spectra were identical with those recorded for the racemic compound.

(−)-*Campherenol* (16).—A solution of (−)-campherenone (189 mg) in propan-1-ol (50 ml) was treated with sodium (770 mg) and refluxed for 2 h. The solvent was then removed, water was added to the residue, and the solution was extracted with ether. Removal of solvent provided a crude product (195 mg) whose i.r. and t.l.c. characteristics indicated that a considerable amount of starting material was present. The reaction was repeated, therefore, using additional quantities of sodium (1·89 g) and propanol (25 ml) and refluxing the solution for 16 h. Work-up gave a 7 : 1 mixture (190 mg) of (−)-campherenol (16) and (+)-isocampherenol (17). Chromatography over silica (8 g) [elution with petroleum–benzene (5 : 1)] provided (−)-campherenol (16) (130 mg) as an oil, $[\alpha]_D^{22}$ −5·3° (*c* 4·53 in $CHCl_3$) {lit.,[10] $[\alpha]_D$ −62·1° (*c* 3·9 in $CHCl_3$)}; $\nu_{max.}$ (film) 3300 cm^{-1} τ (CCl_4; 60 MHz) 9·18 (3H, s), 9·12 (3H, s), 8·41 (3H, s), 8·36 (3H, s), 6·00br (1H, d), and 4·96br (1H, t).

(−)-β-*Santalene* (18).—The procedure used was identical

* Because of the minor role played by (+)-epicampherenone in our general synthetic plan no attempt was made to improve this yield; *cf.* synthesis of campherenone (15).

with that described for the racemic series.[1] Reduction of (−)-campherenone (15) with lithium hydridotrimethoxyaluminate gave (+)-isocampherenol (17), $[\alpha]_D^{32}$ +25° (*c* 2·6 in $CHCl_3$) {lit.,[11] $[\alpha]_D$ +15·3° (*c* 2·6 in $CHCl_3$)} in 95% yield. Dehydration of (17) with toluene-*p*-sulphonyl chloride in pyridine provided (−)-β-santalene (18), $[\alpha]_D^{28}$ −112° (*c* 5·01 in $CHCl_3$) {lit.,[1] $[\alpha]_D^{20}$ −102° (*c* 5·01 in $CHCl_3$)} in 80% yield.

(+)-*Ylangocamphor* (24) *and* (+)-*Copacamphor* (25) (5-*Isopropyl*-1,7a-*dimethylperhydro*-1,4-*methanoinden*-8-*one*).—Appropriate amendments were made to the large-scale cyclization–dehydration–reduction sequence employed in the racemic series.[1] Pure (+)- or (−)-campherenone (15) (2·5 g) was employed as starting material and distillation after the dehydration step was omitted. Thus the total sequence was carried out without purification of the intermediates and the crude product (1·6 g) obtained after the final hydrogenation step was chromatographed on alumina (65 g; neutral, grade 4). Elution with pentane provided (+)-ylangocamphor, $[\alpha]_D^{27}$ +54° (*c* 3·05 in $CHCl_3$) {lit.,[14] $[\alpha]_D^{26}$ −57·7° ($CHCl_3$) for enantiomer}, followed shortly by (+)-copacamphor, $[\alpha]_D^{22}$ +100° (*c* 1·21 in $CHCl_3$) {lit.,[15a] $[\alpha]_D^{23}$ +106°; lit.,[17] $[\alpha]_D$ +98·7° (*c* 1·7 in $CHCl_3$)}.

(−)-*Sativene* (28) *and* (−)-*Copacamphene* (29) (7-*Isopropyl*-4-*methyl*-8-*methyleneperhydro*-1,4-*methanoindene*).—The procedure (Scheme 4) described for the racemic series [1] was used and (−)-sativene (28), $[\alpha]_D^{27}$ −178° (*c* 1·32 in $CHCl_3$) {lit.,[17] $[\alpha]_D$ −186° ($CHCl_3$)}, was obtained from (+)-ylangocamphor (24) in *ca.* 50% overall yield. The n.m.r. and i.r. spectra were identical with those reported [1,18] for (±)-sativene.

An identical sequence of reactions (Scheme 4) starting with (+)-copacamphor (25) gave a product which was purified by chromatography over alumina (grade I) to provide (−)-copacamphene (29),* $[\alpha]_D$ −141° (*c* 9·64 in $CHCl_3$) (lit.,[15b] $[\alpha]_D$ −159°), in *ca.* 60% overall yield.

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* A previous report [17] describing the conversion of natural (+)-copaborneol (27; OH-*endo*) into copacamphene ($[\alpha]_D$ + 28°) is inconsistent with our results and those of our colleagues.[15b]

[17] M. Kolbe-Haugwitz and L. Westfelt, *Acta Chem. Scand.*, 1970, **24**, 1623.

[18] P. de Mayo and R. E. Williams, *J. Amer. Chem. Soc.*, 1965, **87**, 3275.