A Synthesis of Functionalised Tricyclo[5.2.2.0^{1,5}]undecenes related to the Isoeremolactone Skeleton

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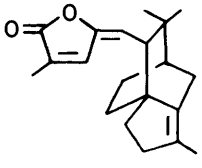
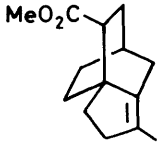
Synthesis of methyl 4,8-dimethyltricyclo[5.2.2.0^{1,5}]undeca-4(and 5),8-diene-9-carboxylate (**3**), as a synthon for isoeremolactone, is described. The key steps are the double Michael addition of the enolate of 3-[3,3-ethylenedioxybutyl]cyclohex-2-en-1-one (**9**), prepared from *m*-methoxyphenylbut-3-en-2-one (**4**), to methyl 2-(ethylthio)but-2-enoate leading to the bicyclo[2.2.2]octanone intermediate (**12**) and the intramolecular aldol condensation of the deprotected diketone (**13**) to construct the third five-membered carbocyclic ring.

The isolation of eremolactone and several related compounds from the crude oil of *Eremophila fraseri*[1] and *E. freelingii*[2] introduced a new family of diterpenes which was shown by the *X*-ray analysis of isoeremolactone (**1**)[3] to possess the unique tricyclo[5.2.2.0^{1,5}]undecene carbon skeleton. (±)-Eremolactone[4] and (+)-isoeremolactone[5] have recently been synthesized *via* a Lewis acid-induced double Michael reaction in the former, and a Lewis acid-catalysed skeletal rearrangement of tricyclovetivene epoxide in the latter, to construct the tricycloundecene carbon skeleton. Such a tricyclo-undecene framework has also been obtained *via* a Diels–Alder reaction.[6,7] Our growing interest in the application of sequential Michael reactions to natural product synthesis,[8] and the recent work by Kraus and co-workers[9] concerning the synthesis of methyl 4-methyltricyclo[5.2.2.0^{1,5}]undec-4-ene-9-carboxylate (**2**) by applying a base-induced double Michael reaction, prompts us to report our results concerning the synthesis of methyl 4,8-dimethyltricyclo[5.2.2.0^{1,5}]undeca-4(and 5),8-diene-9-carboxylate (**3**) through the double Michael reaction developed independently by the use of α-hetero-substituted crotonic acid esters in our laboratory.



(**1**)



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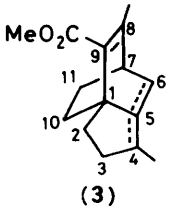
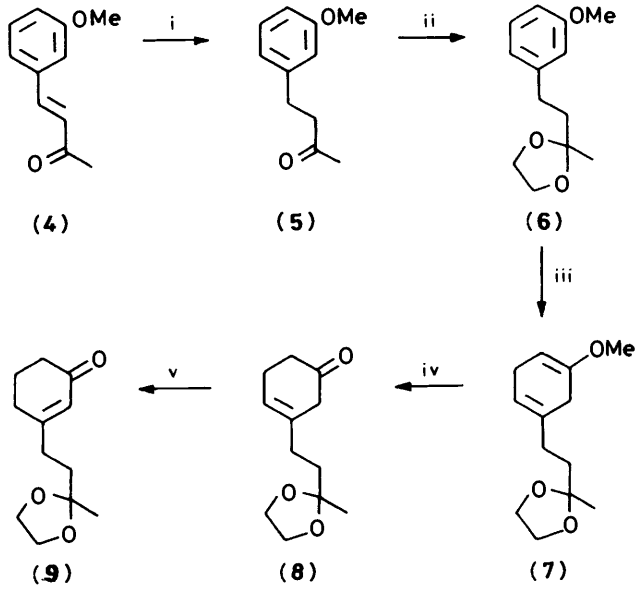


(**3**)

Our first step was to prepare the key enone component (**9**), and *m*-methoxyphenylbut-3-en-2-one (**4**)[10] was chosen as the most suitable starting material (Scheme 1). The ketone (**4**) was hydrogenated over Pd–C to give the saturated ketone (**5**), which was transformed into the ethylene acetal (**6**) in the usual manner.

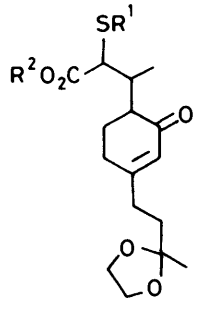
The Birch reduction of compound (**6**), followed by hydrolysis of the resulting dihydro derivative (**7**) with aqueous methanolic oxalic acid, afforded a mixture of the enones (**8**) and (**9**) in high yield. Treatment of the mixture with sodium methoxide in methanol furnished the pure enone (**9**).

For the construction of a bicyclo[2.2.2]octane skeleton by applying a double Michael reaction to the enone (**9**), we examined first the use of ethyl 2-(phenylthio)but-2-enoate. Despite the successful double Michael addition to 3-methylcyclohex-2-en-1-one giving a bicyclo[2.2.2]octanone derivative,[8a] the reaction of the kinetically controlled enolate of



Scheme 1. *Reagents and conditions:* i, H_2–Pd–C–EtOH; ii, $HOCH_2$-CH_2OH–*p*TsOH–benzene, reflux; iii, Li–liquid NH_3–THF–Bu^{t}OH; iv, $(CO_2H)_2$–MeOH–H_2O; v, NaOMe–HOMe

the enone (**9**) with ethyl 2-(phenylthio)but-2-enoate, in the presence or absence of hexamethylphosphoric triamide, afforded only the single Michael adduct (**10**). Attempts to conduct the double Michael reaction by employing 2-ethylthio or 2-ethylsulphinyl-3-methylbut-2-enoate resulted in the complete re-

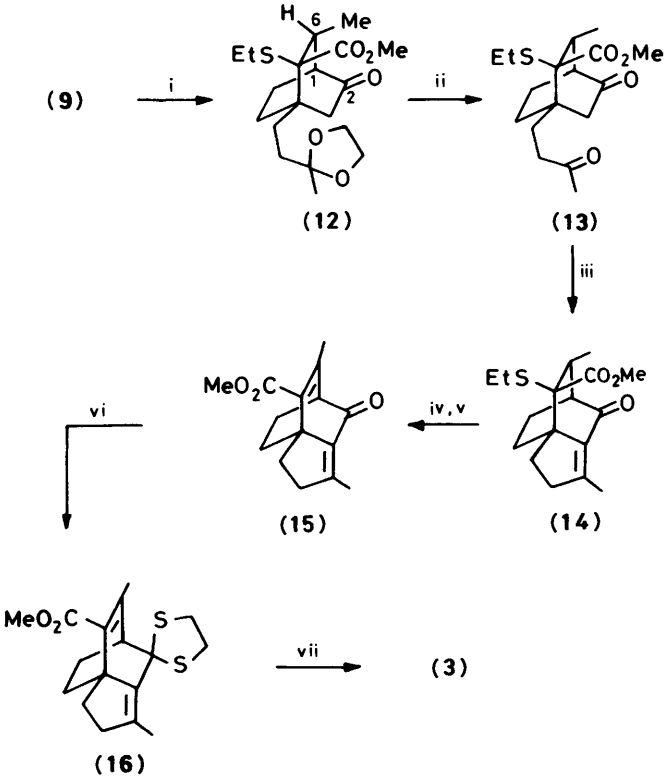


(**10**) R^1 = Ph, R^2 = Et
(**11**) R^1 = Et, R^2 = Me

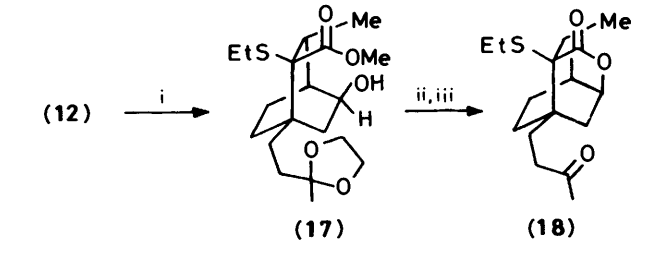
covery of the starting enone (**9**). Careful experiments on reactions and quenching temperatures produced the same results.

Then, less bulky and less polar methyl 2-(ethylthio)but-2-enoate was chosen as a partner to promote the second stage of the double Michael reaction.

As expected, when the reaction of the enolate of the enone (**9**) with methyl 2-(ethylthio)but-2-enoate (5:2 mixture of *Z* and *E* isomers) was conducted at −30 °C and quenched below −10 °C, the double Michael adduct (**12**) was obtained (74% yield) (Scheme 2), whereas quenching of the reaction at room temperature resulted in the formation of only the single Michael adduct (**11**). Compound (**12**) seems to be a single isomer, judging by the observed simplicity of the n.m.r. signals as well as those of compounds (**13**) and (**14**). The relative configuration of the ester group could be *syn* to the carbonyl group at C-2 as indicated by the fact that the tricyclic lactone (**18**) was obtained after a series of reactions. Thus, reduction of the keto group with sodium borohydride to give the hydroxyester (**17**) followed by hydrolysis of the ester and acid-catalysed cyclisation led to the lactone (**18**). The stereochemistry of the secondary methyl group at C-6 was examined in the hydroxyester (**17**), and was assumed to be *syn* in relation to the hydroxy group because of a large downfield shift (1.06 p.p.m.) in the presence of [Eu(dpm)$_3$] (0.042 mmol) in the n.m.r. spectrum (Scheme 3). The configuration of the substituents, however, is of no consequence because the stereochemistry at this moiety vanishes in the final compound (**3**).



Scheme 2. *Reagents and conditions:* i, LDA–THF–hexane, −50 to −40 °C, then MeCH=C(SEt)CO_2Me, −30 °C; ii, AcOH–H_2O, 80 °C; iii, $PhCO_2H$–pyrrolidine–benzene, reflux; iv, MCPBA–CH_2Cl_2, −55 °C; v, xylene–pyridine, reflux; vi, $HSCH_2CH_2SH$–BF_3·OEt_2, warm; vii, Raney-Ni (W-2)–EtOH, reflux



Scheme 3. *Reagents and conditions:* i, $NaBH_4$–MeOH, −70 to −50 °C; ii, KOH–dioxane, reflux; iii, *p*-TsOH–benzene, reflux

Treatment of the deprotected diketone (**13**) with a mixture of pyrrolidine and benzoic acid in refluxing benzene gave the crystalline tricyclic enone (**14**) in 54% yield. Oxidation of compound (**14**) with *m*-chloroperbenzoic acid at low temperature followed by pyrolysis of the resulting sulphoxide in refluxing xylene produced the dienone carboxylate (**15**) in 79% yield. Reduction of the keto group by the usual thioacetalisation-reductive desulphurisation procedure furnished compound (**3**) (62%). Compound (**3**) thus obtained consists of Δ^4 and Δ^5 isomers in almost equal amounts as observed by the signals due to the C-4 secondary methyl (δ 0.95) and olefinic methyl (δ 2.03) groups. Unfortunately, at present, all attempts to introduce an additional methyl group or its equivalent at C-8 in compound (**3**), thus leading to the most promising precursor of isoeremolactone (**1**), under a wide variety of conditions have been unsuccessful. The use of compounds having a formyl or an acetyl group instead of the methoxycarbonyl one in compound (**3**) has also been unsatisfactory. The sterically crowded environment of the bicyclo[2.2.2]octane moiety may be an obstacle to the approach of reagents.

Experimental

Small amounts of liquids were normally purified by evaporative short-path distillation; oil-bath temperatures are recorded. I.r. spectra were obtained for solutions in carbon tetrachloride (unless otherwise indicated) with a Hitachi EPI-G2 spectrophotometer. ^{1}H N.m.r. spectra for solutions in carbon tetrachloride (unless otherwise indicated) were recorded with a Jeol C-60HL or PMX-60 instrument, with tetramethylsilane as internal standard. Mass spectra were obtained on a Shimadzu LKB-9000 or a Jeol JMS-DX 300 spectrometer. Microanalyses were carried out in the microanalytical laboratory of this Institute. Ether for extractions and chromatographies refers to diethyl ether. Light petroleum refers to the fraction boiling in the range 35—50 °C.

4-(m-*Methoxyphenyl*)*butan*-2-*one* (**5**).—A solution of *m*-methoxyphenylbut-3-en-2-one (**4**)[10] (9.9 g) in ethanol (100 ml) was hydrogenated over 5% Pd–C (920 mg) under 1 atm of hydrogen at room temperature overnight. After removal of the catalyst, the solvent was evaporated to dryness and the residual oil was distilled to give the *ketone* (**5**) (9.3 g, 93%); b.p. 140 °C at 2 mmHg; $\nu_{max.}$(neat) 1 710, 1 600, 1 580, 1 480, 1 250, 1 150, 1 040, 780, and 690 cm^{-1}; δ 1.95 (3 H, s, MeCO), 2.63 (4 H, m), 3.65 (3 H, s, OMe), and 6.45—7.25 (4 H, m, ArH) (Found: C, 74.2; H, 8.1%; M^+, 178. $C_{11}H_{14}O_2$ requires C, 74.1; H, 7.9%; M^+, 178).

4-(m-*Methoxyphenyl*)*butan*-2-*one Ethylene Acetal* (**6**).—A solution of the butanone (**5**) (13.5 g, 76 mmol), ethylene glycol (6 ml), and fused toluene-*p*-sulphonic acid (200 mg) in anhydrous benzene (170 ml) was heated under reflux for 19 h using a Dean-Stark water-separator. After cooling to room temperature, the reaction mixture was washed with aqueous sodium hydrogen carbonate, water, and brine, and evaporated to dryness. Distillation of the residue gave the *acetal* (**6**) (13.3 g, 81%), b.p.

130—132 °C at 1 mmHg; $\nu_{max.}$ 1 600, 1 490, 1 260, 1 160, and 1 060 cm^{-1}; δ 1.28 (3 H, s, Me), 1.67—2.00 (2 H, m), 2.45—2.80 (2 H, m), 3.70 (3 H, s, OMe), 3.85 (4 H, s, OCH_2CH_2O), and 6.45—7.30 (4 H, m, ArH) (Found: C, 70.2; H, 8.3. $C_{13}H_{18}O_3$ requires C, 70.2; H, 8.2%).

4-(5-*Methoxycyclohexa*-1,4-*dienyl*)*butan*-2-*one Ethylene Acetal* (**7**).—To stirred liquid ammonia (*ca.* 300 ml, distilled over sodium metal) under nitrogen and with methanol–solid CO_2 cooling was added dropwise a solution of the acetal (**6**) (8.9 g, 42 mmol) in anhydrous THF (50 ml) and t-butyl alcohol (50 ml). Small pieces of lithium metal (3.81 g, 0.544g-atom) were then added portionwise after which the cooling bath was removed and the mixture refluxed for 4 h using a cold-finger (methanol–solid CO_2). Storage overnight at room temperature expelled most of the ammonia from the mixture after which aqueous ammonium chloride was added and the product extracted twice with ether. The combined extracts were washed with aqueous ammonium chloride until neutral (litmus), water, and brine. Evaporation of the ether left the crude *enol-ether* (**7**) (9.94 g, over 100%), b.p. 95—102 °C at 0.2 mmHg; $\nu_{max.}$ 1 695, 1 665, 1 220, and 1 030 cm^{-1}; δ 1.25 (3 H, s, Me), 1.40—2.25 (4 H, m), 2.38—2.91 (4 H, br s), 3.48 (3 H, s, OMe), 3.81 (4 H, s, OCH_2CH_2O), 4.52 (1 H, br s, $W_{\frac{1}{2}}$ 7 Hz, 4-H), and 5.37 (1 H, br s, $W_{\frac{1}{2}}$ 7 Hz, 2-H) (Found: C, 69.4; H, 8.9. $C_{13}H_{20}O_3$ requires C, 69.6; H, 9.0%).

3-[(3,3-*Ethylenedioxy*)*butyl*]*cyclohex*-2-*en*-1-*one* (**9**).—To a solution of the enol-ether (**7**) (1.42 g, 6.34 mmol) in methanol (10 ml) was added saturated aqueous oxalic acid (3 ml), and the resulting solution was stirred at room temperature for 2 h. After removal of the methanol under reduced pressure, the product was extracted twice with ether. The combined extracts were washed with water and brine. Evaporation of the ether gave a mixture of the isomeric enones (**8**) and (**9**) (1.39 g, quantitative); $\nu_{max.}$ 1 720, 1 675, 1 630, 1 450, 1 375, 1 340, 1 250, and 1 215 cm^{-1}.

A solution of the above mixture (3.77 g, 17.9 mmol) in methanol (40 ml) containing sodium methoxide [prepared from sodium hydride (244 mg, 5 mmol)] was stirred at room temperature for 2.5 h. Aqueous ammonium chloride was added, and the methanol was evaporated under reduced pressure. The residue was extracted with ether, and the extract was washed with water and brine. Evaporation of the ether, followed by evaporative distillation gave the *enone* (**9**) (3.41 g, 90%), b.p. 120—130 °C at 1 mmHg; $\nu_{max.}$ 1 675, 1 630, 1 370, 1 245, 1 130, and 1 050 cm^{-1}; δ 1.25 (3 H, s, Me), 1.40—2.50 (10 H, m), 3.89 (4 H, s, OCH_2CH_2O), and 5.80 (1 H, br m, =CH–) (Found: C, 68.3; H, 9.0%; M^+, 210. $C_{12}H_{18}O_3$ requires C, 68.6; H, 8.6%; M^+, 210).

Methyl 2-(*Ethylthio*)*but*-2-*enoate*.—Methyl 2-(ethylthio)but-2-enoate was prepared by heating a mixture of methyl 2-bromobut-2-enoate, ethanethiol, potassium bromide, and triethylamine according to the procedure of Gundermann and Schulze;[11] b.p. 80—90 °C at 3 mmHg; δ 1.16 (3 H, t, *J* 7.5 Hz, *Me*CH_2), 2.00 (3 H, d, *J* 6.5 Hz, *Me*CH=), 2.71 (2 H, q, *J* 7.5 Hz, MeCH_2), 3.71 (3 H, s, CO_2Me), and 7.20 (1 H, q, *J* 6.5 Hz, MeCH=).

The ratio of the *E*- and *Z*-isomers was determined in the following way. Oxidation of the ethylthiobutenoate with *m*-chloroperbenzoic acid was carried out in the usual manner to give quantitatively an inseparable mixture of isomers of methyl 2-ethylsulphinylbut-2-enoate; δ (the major *Z*-isomer) 1.13 (t, *J* 7.5 Hz, *Me*CH_2), 2.30 (d, *J* 7 Hz, *Me*CH=), 3.80 (s, CO_2Me), and 6.83 (q, *J* 7 Hz, –CH=); and δ (minor *E*-isomer) 1.29 (t, *J* 7.5 Hz, *Me*CH_2), 2.01 (d, *J* 7 Hz, *Me*CH=), 3.75 (s, CO_2Me), and 7.45 (q, *J* 7 Hz, –CH=). The ratio (5:2) of the major *Z*- and minor *E*-isomers was determined by comparison of the peak areas of the olefinic methyl signals at δ 2.30 [*Z*-configuration, shifted markedly down field (0.3 p.p.m.) upon conversion of the EtS group into the EtS(O) group][12] and 2.01, respectively.

Methyl 5-*Ethylthio*-6-*methyl*-2-*oxo*-4-(3-*oxobutyl*)*bicyclo*-[2.2.2]*octane*-5-*carboxylate* (**13**).—To a solution of lithium di-isopropylamide (3.82 mmol) in anhydrous THF (3 ml) and hexane (2.8 ml) was added dropwise a solution of the enone (**9**) (630 mg, 3 mmol) in THF (4 ml) at −55 to −40 °C for 30 min. A solution of methyl 2-(ethylthio)but-2-enoate (598 mg, 3.74 mmol) in THF (4 ml) was added, and the resulting mixture was stirred at −30 °C for 45 min. Aqueous ammonium chloride was added, and the product was extracted with ether. The combined extracts were washed with water and brine, and evaporated to dryness. Chromatography of the residue on silica gel (eluant ether) gave methyl 5-ethylthio-6-methyl-2-oxo-4-[(3,3-ethylenedioxy)butyl]bicyclo[2.2.2]octane-5-carboxylate (**12**) (822 mg, 74%); $\nu_{max.}$ 1 730, 1 450, 1 380, 1 220, 1 080, and 1 060 cm^{-1}; δ 0.92 (3 H, d, *J* 7 Hz, *Me*CH), 1.22 (6 H, br s, *Me*CH_2 and MeC), 1.08—3.10 (12 H, m), 3.70 (3 H, s, CO_2Me), and 3.83 (4 H, s, OCH_2CH_2O) (Found: M^+, 370. $C_{19}H_{30}O_5S$ requires *M*, 370). Evaporative distillation (130 °C at 0.15 mmHg) resulted in partial decomposition.

A solution of the bicyclic keto-ester (**12**) (250 mg) in acetic acid (4 ml) and water (3 ml) was heated at 80 °C for 45 min. After cooling to room temperature, the reaction mixture was poured into aqueous sodium hydrogen carbonate and extracted with ether. The combined extracts were washed with water and brine. Evaporation of the solvent gave the diketo-ester (**13**) (215 mg, 98%); $\nu_{max.}$ 1 720, 1 445, 1 430, 1 350, 1 220, and 1 150 cm^{-1}; δ 0.87—1.40 (6 H, m, *Me*CH_2 and *Me*CH), 1.43—3.20 (14 H, m), 2.08 (3 H, s, MeCO), and 3.77 (3 H, s, CO_2Me) (Found: M^+, 326. $C_{17}H_{26}O_4S$ requires *M*, 326).

Methyl 5-*Ethylthio*-2-*hydroxy*-6-*methyl*-4-[(3,3-*ethylenedioxy*)*butyl*]*bicyclo*[2.2.2]*octane*-5-*carboxylate* (**17**).—To a solution of bicyclic keto-ester (**12**) (75 mg, 0.2 mmol) in methanol (2 ml) was added sodium borohydride (10 mg, 0.27 mmol) at −70 °C, and the resulting solution was stirred at −70—−50 °C for 30 min. The reaction mixture was poured into water and extracted with ether. Evaporation of the solvent followed by chromatography of the residue on silica gel [eluant hexane–ethyl acetate (1:3)] gave the bicyclic hydroxyester (**17**) (37 mg, 49%); $\nu_{max.}$ 3 600, 3 500, 1 730, 1 710, 1 600, 1 480, 1 460, 1 360, 1 220, and 1 140 cm^{-1}; δ($CDCl_3$) 1.18 (3 H, t, *J* 7 Hz, *Me*CH_2S), 1.19 (3 H, d, *J* 7 Hz, *Me*CH), 1.30 (3 H, s, acetal Me), 1.1—2.2 (m, 13 H), 2.43 (2 H, q, *J* 7 Hz, MeCH_2S), 3.20 (1 H, m, C*H*OH), 3.73 (3 H, s, CO_2Me), and 3.91 (4 H, s, OCH_2CH_2O).

4-*Ethylthio*-5-*methyl*-9-(3-*oxobutyl*)-2-*oxatricyclo*-[4.4.0.0^{4,9}]*decan*-3-*one* (**18**).—A solution of the bicyclic hydroxyester (**17**) (37 mg, 0.1 mmol) and potassium hydroxide (67 mg, 1.2 mmol) in dioxane (2 ml) and water (5 ml) was heated under reflux overnight. After cooling in an ice-bath, the resulting solution was acidified with dilute hydrochloric acid (10%) to pH 2. The product was extracted with ether, and used without further purification; $\nu_{max.}$($CHCl_3$) 3 500, 3 000, 1 710, and 1 130 cm^{-1}. A solution of the bicyclic hydroxy acid and toluene-*p*-sulphonic acid (10 mg, 0.06 mmol) in anhydrous benzene (20 ml) was heated at reflux using a Dean-Stark water separator for 2 h. After being cooled to room temperature, the organic layer was washed with aqueous sodium hydrogen carbonate, and the aqueous layer was extracted with ether. Evaporation of the combined organic layers under reduced pressure, followed by chromatography of the residue on silica gel [eluant hexane–ethyl acetate (1:1)] afforded the *tricyclic lactone* (**18**) [6 mg, 20% overall from the hydroxyester (**17**)] as a major product; $\nu_{max.}$ 1 760, 1 720, 1 380, 1 345, and 1 120 cm^{-1};

δ($CDCl_3$) 1.26 (3 H, t, *J* 7 Hz, *Me*CH_2S), 1.26 (3 H, d, *J* 7 Hz, *Me*CH), 2.14 (3 H, s, COMe), 1.0—3.2 (14 H, m), and 4.70 (1 H, m, $W_{\frac{1}{2}}$ 12 Hz, CHOCO) [Found: *m/z* (M^+) 296.1450. $C_{16}H_{24}O_3$ requires *M*, 296.1446.]

Methyl 9-Ethylthio-4,8-dimethyl-6-oxotricyclo[5.2.2.0^{1,5}]*undec-4-ene-9-carboxylate* (**14**).—A solution of the diketo-ester (**13**) (215 mg, 0.66 mmol) in anhydrous benzene (30 ml) containing benzoic acid (65 mg, 0.59 mmol) and pyrrolidine (46 mg, 0.59 mmol) was heated under reflux for 1.5 h using a Dean-Stark water-separator. After being cooled to room temperature, the reaction mixture was washed with aqueous sodium hydrogen carbonate, water, and brine, and evaporated to dryness. Preparative t.l.c. of the residue on silica gel [eluant light petroleum–ether (1:1)] gave the tricyclic enone-ester (**14**) (110 mg, 54%), m.p. 98—100 °C (from light petroleum–ether); $\nu_{max.}$ 1 720, 1 690, 1 640, 1 610, 1 445, 1 430, 1 370, 1 250, and 1 150 cm^{-1}; δ($CDCl_3$) 1.22 (3 H, d, *J* 7 Hz, *Me*CH), 2.10 (3 H, br s, MeC=), 0.90—3.10 (15 H, m), and 3.62 (3 H, s, CO_2Me) (Found: M^+, 308. $C_{17}H_{24}O_3S$ requires *M*, 308).

Methyl 4,8-Dimethyl-6-oxotricyclo[5.2.2.0^{1,5}]*undeca-4,8-diene-9-carboxylate* (**15**).—To a solution of the ethylthio enone ester (**14**) (428 mg, 1.39 mmol) in anhydrous methylene dichloride (4 ml) was added dropwise a solution of *m*-chloroperbenzoic acid (85%, 282 mg, 1.39 mmol) in methylene dichloride (5 ml) at −55 °C. After being stirred for 40 min, the reaction mixture was diluted with methylene dichloride and poured into aqueous sodium hydrogen carbonate. The organic layer was washed with water and brine. Evaporation of the solvent left the ethylsulphinyl-enone-ester (480 mg, over 100%). This compound was dissolved in a mixture of anhydrous xylene (4 ml) and pyridine (1 ml), and the resulting solution was heated under reflux for 1 h. Evaporation of the solvent under reduced pressure, followed by preparative t.l.c. of the residue on silica gel (eluant ether) gave, in addition to the recovered ethylthio enone ester (**14**) (108 mg, 25%), the dienone-ester (**15**) (240 mg, 70%); m.p. 102—103 °C (from light petroleum–ether); $\nu_{max.}$ 1 715, 1 695, 1 665, 1 430, 1 340, 1 250, 1 210, 1 200, 1 085, and 1 065 cm^{-1}; δ 1.50—1.80 (4 H, m), 1.80—2.40 (2 H, m), 2.00 (6 H, s, 2 × MeC=), 2.40—2.80 (2 H, m), 3.05 (1 H, br s, 7-H), and 3.70 (3 H, s, CO_2Me) (Found: M^+, 246. $C_{15}H_{18}O_3$ requires *M*, 246).

Methyl 4,8-Dimethyltricyclo[5.2.2.0^{1,5}]*undeca-4*(*and* 5),8-*diene-9-carboxylate* (**3**).—A mixture of the dienone-ester (**15**) (500 mg), ethanedithiol (0.1 ml), and boron trifluoride–ether (1 drop) was warmed in a hot water-bath for 20 min. The reaction mixture was diluted with ether, and the organic layer was washed with aqueous sodium hydrogen carbonate, water, and brine. Evaporation of the solvent left methyl 4,8-dimethyl-6,6-ethylenedithiotricyclo[5.2.2.0^{1,5}]undeca-4,8-diene-9-carboxylate (**16**) (762 mg, quantitative); $\nu_{max.}$ 1 710, 1 430, 1 340, 1 270, 1 240, 1 200, and 1 065 cm^{-1}; δ 1.80 (3 H, s, MeC=), 2.03 (3 H, s, MeC=), 1.30—2.80 (9 H, m), 3.28 (4 H, s, SCH_2CH_2S), and 3.65 (3 H, s, CO_2Me) (Found: M^+, 322. $C_{17}H_{22}O_2S_2$ requires *M*, 322).

A slurry of the thioacetal (**16**) (200 mg) and Raney-Ni (W-2; 3 ml) in ethanol (7 ml) was heated under reflux for 30 min. The Raney-Ni was removed by filtration through a Celite column. Evaporation of the solvent, followed by preparative t.l.c. of the residue on silica gel [eluant light petroleum–ether (1:3)] gave a mixture (*ca.* 1:1) of the isomeric diene-ester (**3**) (90 mg, 62%); $\nu_{max.}$ 1 710, 1 620, 1 620, 1 435, 1 255, 1 205, and 1 070 cm^{-1}; δ 0.95 (3 H, d, *J* 6 Hz, 4-*Me*), 1.97 (3 H, s, MeC=), 2.03 (3 H, br s, 4-MeC=), 1.20—2.70 (m), 3.65 (3 H, s, CO_2Me), and 5.72 (1 H, m, 6-CH=) (Found: M^+, 232. $C_{15}H_{20}O_2$ requires *M*, 232).

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