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APPROACHES TO BICYCLIC RING SYSTEMS *VIA* 1, 5 ALLYLIC ABSTRACTION CYCLISATION

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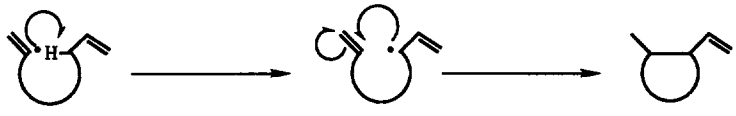
Abstract: A new 1, 5 allylic abstraction, cyclisation sequence has been developed and applied to the synthesis of fused bicyclic systems. Initial studies directed towards the synthesis of the bicyclo[3.3.0] octane skeleton are described: vinyl bromide **4** was subjected to standard cyclisation conditions to give **5** as a single isomer. Further studies were directly related to the development of the rearrangement sequence: vinyl bromide **10** was subjected to cyclisation conditions to give **12** in moderate yield. A significant improvement in the rate and efficiency of this type of conversion was achieved by introducing an electron withdrawing group on the acceptor alkene, thus compound **17** gives **18** in excellent yield.

Aims

Previous studies from this laboratory had shown that a radical rearrangement (vinyl to allylic radical) could be employed in the synthesis of five membered heterocyclic systems useful in natural product synthesis[1]. We were fascinated by the possibility that this method could have wider applications and therefore decided to investigate the process with a view to accessing carbocyclic systems (scheme 1).

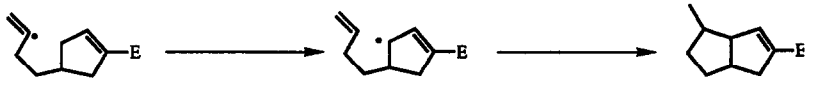


Scheme 1

We have recently reported the realisation of this goal with the development of an approach which provides access to highly functionalised carbocyclic systems in moderate to good yield[2]. In this paper we will describe our work which begins to delineate the scope and limitations of this type of cyclisation reaction.

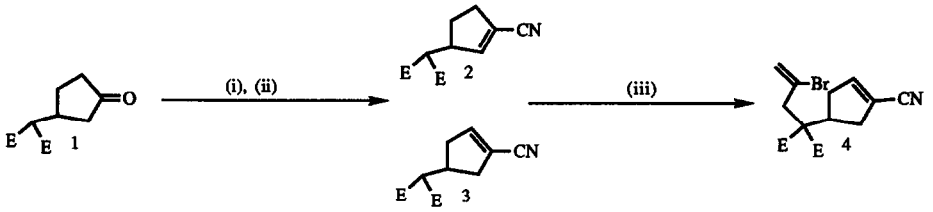
Results and Discussion

For a number of synthetic purposes our initial investigations centred around the construction of the bicyclo [3.3.0] octane system; we were interested in evaluating an approach which is exemplified in scheme 2.



Scheme 2

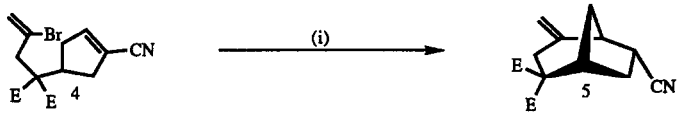
We decided that the first precursor we required for our investigations was **4** which was synthesised in a three step sequence (scheme 3). Treatment of the Michael adduct **1**[3] with trimethylsilyl cyanide and elimination of the crude protected cyanohydrin with phosphoryl chloride, pyridine and DBU at reflux[4] led us to isolate the desired α,β unsaturated nitrile **3** along with the undesired geometric isomer **2** in reasonable yield (66%, 1:1 mixture), these could be separated using hplc. We were particularly disappointed to find that on the larger scale (>1g) the yield of this transformation dropped drastically to around 30%, the reaction was somewhat capricious and is not recommended as a synthetic route to compounds of this type. However with reasonable quantities of the desired material in hand we were able to construct the desired precursor from **3** *via* alkylation with 2,3-dibromopropene to give **4** in 78% yield.



Reagents; (i) TMSCN, CH_2Cl_2, ZnI_2, r.t.; (ii) $POCl_3$, Pyridine, DBU, Δ 66% (two steps); (iii) KH, THF, HMPA, 2,3 - dibromopropene, r.t., 78%

Scheme 3

Treatment of **4** under standard tri-*n*-butyltin hydride conditions led us to isolate a new cyclised material **5** in 37% yield whereby a facile 6-*exo*-trig cyclisation has taken place with no other products being isolated from the reaction mixture.

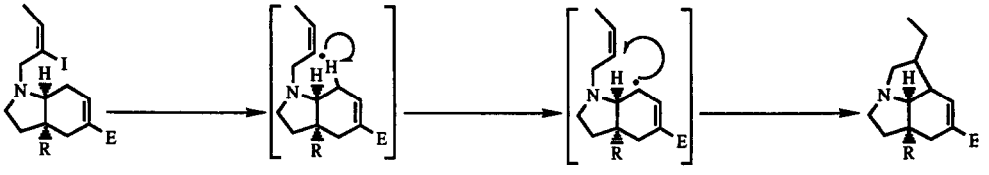


Reagents; (i) Bu_3SnH, AIBN, Benzene, Δ, 37%

Scheme 4

The product was isolated as one isomer with the stereochemistry determined by irradiation and n.O.e experiments as outlined in the experimental section.

We believe that the failure of the rearrangement in this particular system was due to the choice of substrate as we had previously shown that such a rearrangement can take place in the presence of an electron deficient alkene (scheme 5)[1].



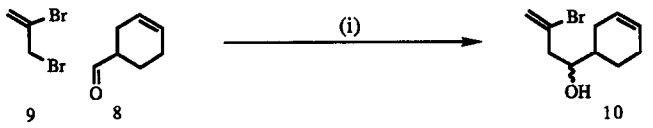
6 6a 6b 7

Reagents; (i) Bu_3SnH, AIBN, Benzene, Δ, 60 - 85%

Scheme 5

Examination of molecular models shows that the vinyl radical **6a** is unlikely to undergo 6-*exo*-trig cyclisation but that the abstraction **6a-6b** is geometrically very favourable[5]. However in the studies of the

carbocyclic series (attempted cyclisation of substrate **4** in scheme 4) either pathway could be envisaged. We decided to attempt to design model systems which would avoid or at least minimise the 6-*exo*-trig pathway; with these criteria in mind we decided that **10** would serve as a useful precursor to continue the study. We suspected that the alkenyl side chain containing the vinyl bromide would prefer to adopt a pseudo-equatorial conformation in the transition state, this coupled with the absence of an electron withdrawing group on the alkene led us to believe that only rearrangement or reduction should take place. Treatment of 1,2,5,6-tetrahydrobenzaldehyde with 2,3-dibromopropene under the conditions shown[6] in scheme 6 led us to isolate a 79% yield of the desired precursor **10** as an inseparable mixture of diastereoisomers (1:1).

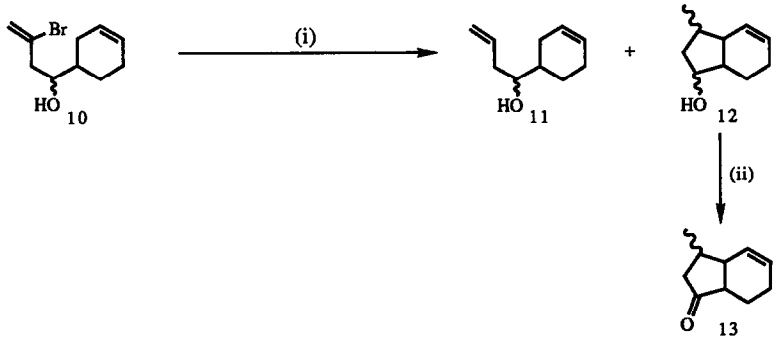


9 8 10

Reagents; (i) Sn dust, HBr, AcOH, Et_2O:H_2O (1:1), 79%

Scheme 6

A variety of conditions were used in an attempt to mediate the desired cyclisation but initially experiments gave only traces (c.a. 5%) of the desired material **12** which we could see from the ^1H n.m.r. was a mixture of four diastereoisomers. We were delighted to find that when we subjected our precursor to the so called "catalytic tin" conditions a 27% yield of the desired product was isolated[7]. We found that this reaction was extremely sensitive to the purity of the sodium cyanoborohydride and the yield could be improved to an acceptable 43% if the reaction was allowed to stir at reflux for three days (scheme 7). It was gratifying for us to note that the reduction product **11** was isolated in only 20% yield, thus the rearrangement sequence was *the major pathway*. Oxidation of the inseparable diastereoisomeric mixture (4 diastereoisomers) **12** using either Swern or PDC led to the isolation of **13** as a 1:1 mixture of two inseparable diastereoisomers. The reduction product **11** was isolated as an inseparable mixture (1:1) of diastereoisomers; this material was independently synthesised to give the same mixture in 97% yield (see experimental section)

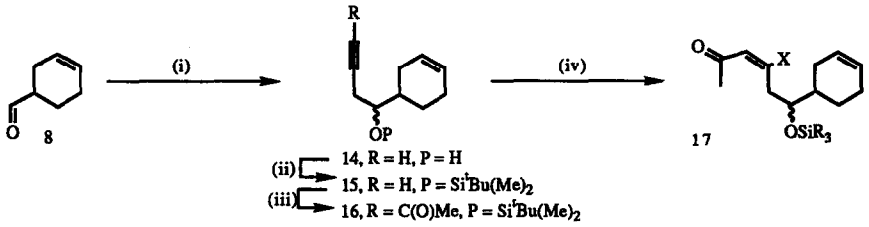


10 11 12 13

Reagents; (i) Bu_3SnCl, $NaCNBH_3$, t-BuOH, AIBN, Benzene, Δ, 3 days, 63% (1:2); (ii) PDC, CH_2Cl_2, r.t., 49%

Scheme 7

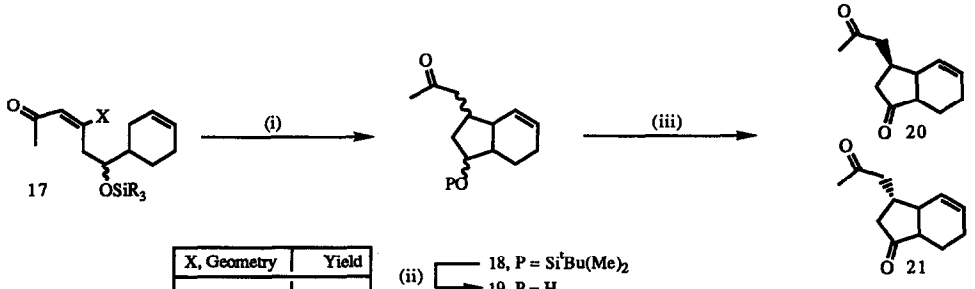
In order to improve the rate of this sequence we assumed that the cyclisation was the slow step and decided to introduce an electron withdrawing group onto the acceptor alkene, scheme 8 shows the construction of another precursor **17**, using an unoptimised sequence.



Reagents; (i) Propargyl Magnesium Bromide, Et_2O, r.t., 77%; (ii) TBSCl, Imidazole, DMF, 60 °C, 76%; (iii) n-BuLi, THF, -40°C, 27%; (iv) TMSX, CH_2Cl_2, - 78 °C (X = I , 59%; X = Br, 57%)[8];

Scheme 8

Treatment of the precursors under standard "tin hydride" conditions led us to isolate the desired material as the only product. Table 1 shows that either vinyl bromides or iodides can be utilised and it was extremely gratifying to find that in all cases the reaction times were much shorter than the three days required for the previously described reactions, *using the iodides the reaction was complete after only one hour.* We believe that this rate enhancement is due to presence of the electron withdrawing group on the acceptor alkene. For the purposes of characterisation we were able to desilylate and oxidise the inseparable diastereoisomeric mixture to give the chromatographically separable diketones **20** and **21** in reasonable yield (scheme 9).



X, Geometry	Yield
17a, I, Z	78%
17b, I, E	61%
17c, Br, E	65%
17d, Br, Z	53%

Reagents; (i) Bu_3SnH, AIBN, Benzene, Δ, 1 hr., 78%; (ii) HF, MeCN, H_2O, r.t., 73%; (iii) PDC, CH_2Cl_2, r.t., 62%;

Scheme 9

From a practical standpoint it is worth noting that the vinyl iodides are particularly good precursors for this transformation and their use certainly helps to improve the conversion.

Conclusions

We have illustrated the viability of the 1, 5 allylic abstraction, cyclisation sequence for the construction of bicyclic ring systems which may have synthetic utility in organic synthesis. It would appear from this investigation that, in order to obtain synthetically useful yields of products an electron withdrawing group is required on the acceptor alkene and that geometrically constrained precursors are required. Further investigations which demonstrate that the geometric bias is unnecessary have been ongoing in these laboratories and will be the subject of a further report in the near future.

Experimental

^{1}H nmr spectra were recorded in $CDCl_3$ (unless otherwise stated) using a Jeol GSX 270 or a Bruker AM-360 nmr spectrometer. ^{13}C nmr spectra were recorded in $CDCl_3$ (unless otherwise stated) at 67.5 MHz on a Jeol GSX 270 or at 90.1 MHz on a Bruker AM-360 spectrometer and spectral interpretation was aided using DEPT experiments. Where appropriate tetramethylsilane was used as a standard. Infra-red spectra were recorded on a Perkin-Elmer 298 spectrometer. Mass spectra were recorded, using either a VG Micromass ZAB-E or a VG Analytical 70-250 instruments. Unless otherwise stated all reactions were carried out under an atmosphere of nitrogen using flame dried or oven dried apparatus. Column chromatography was carried out using on Merck Kieselgel 9385 (230-400 mesh). Diethyl ether and tetrahydrofuran solvents were distilled from sodium-benzophenone ketyl; dichloromethane (DCM), acetonitrile, benzene, dichloromethane, dimethylformamide, diisopropylamine, toluene and triethylamine from calcium hydride. Petrol refers to petroleum ether b.p. 40-60°C which was distilled prior to use. Other solvents and reagents were purified by standard procedures as necessary. Analytical thin layer chromatography was performed using pre-coated glass-backed plates (Merck Kieselgel 60 F_{254}) and visualised by ultra-violet light, vanillin, potassium permanganate or iodine as appropriate. Coupling constants are measured in Hertz.

Diethyl-2-[(3-carbonitrile)-2-cyclopentenyl] propanedioate 2 and Diethyl-2-[(3-carbonitrile)-3-cyclopentenyl] propanedioate 3 -Trimethylsilylcyanide (500mg, 5.16mmoles) was added slowly to a stirred solution of *the diester* **1** (970mg, 4.5 mmoles) and zinc iodide (87mg, 0.27mmoles) in dichloromethane (10ml) at room temperature and stirred for fifteen minutes. Phosphoryl chloride (4ml, 42.9mmoles) and pyridine (10ml, 0.123mmoles) were then added cautiously to the reaction mixture and stirred at room temperature for a further ten minutes. Diazobicycloundec-7-ene (3ml) was then added dropwise to the reaction mixture and the reaction heated at reflux overnight. The resultant black mixture was then carefully poured into aqueous hydrochloric acid solution (50ml, 10%) neutralised with saturated sodium bicarbonate solution (6x50ml), extracted with ether (3x50ml). After being dried over sodium sulphate, filtration and removal of the solvent "in vacuo" gave the crude product. Initial separation of the product was carried out by chromatography using petrol : ether (4 : 1) as eluant to give (**2** + **3**) (660mg, 66%) as a (1 : 1) mixture. This material was combined with further mixtures which were separated with a Jobin Yvon Chromatospac hplc apparatus using petrol ether (6 : 1) as eluant to give *the isomeric nitriles* (**2** + **3**) as separate pure compounds.

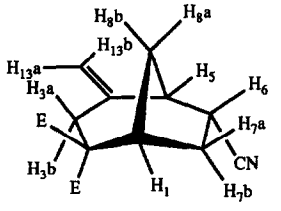
Δ^2 **–Isomer 2** ν_{max} ($CHCl_3$) 2980, 2220, 1730 and 1620 cm^{-1}; δ_H (360 MHz) 6.6 (1H, q, C<u>H</u>), 4.2 (4H, m, $(CO_2C\underline{H}_2)_2$), 3.5 (1H, m, C<u>H</u>), 3.3 (1H, m, J 8.5, $C\underline{H}(CO_2)_2$), 2.6 (2H, m, $C\underline{H}_2$), 2.25 (1H, m), 1.75 (1H, m), 1.2 (6H, t, $(CO_2C\underline{H}_3)_2$); δ_C (90.1 MHz); 167.7 (<u>C</u>O), 149 (<u>C</u>H), 119 (<u>C</u>CN), 116.1 (<u>C</u>N), 61.7 $(CO_2\underline{C}H_2)_2$, 55.2 $(\underline{C}H(CO_2CH_2)_2$, 46 (<u>C</u>H), 33.6 ($\underline{C}H_2$), 27.4 ($\underline{C}H_2$), 14 $(CO_2CH_2\underline{C}H_3)_2$; HRMS found, 251.1159. $C_{13}H_{17}NO_4$ requires $[M]^+$, 251.1157

Δ^3 **–Isomer 3** ν_{max} ($CHCl_3$) 2980, 2220, 1730 and 1620 cm^{-1}; δ_H (360 MHz) 6.6 (1H, m, J 2.4, C<u>H</u>), 4.15 (4H, m, $(CO_2C\underline{H}_2)_2$), 3.35 (1H, d, J 8.8, $C\underline{H}(CO_2)_2$), 3.0 (1H, m, C<u>H</u>), 2.75 (2H, m, $C\underline{H}_2$), 2.4 (2H, m, $C\underline{H}_2$), 1.2 (6H, t, $CO_2C\underline{H}_3$); δ_C (90.1 MHz); 168 (<u>C</u>O), 147.6 (<u>C</u>H), 116 (<u>C</u>N), 113.6 (<u>C</u>CN), 61.6 $(CO_2\underline{C}H_2)_2$, 56 $(\underline{C}H(CO_2CH_2)_2$, 38.2 ($\underline{C}H_2$), 37.7 ($\underline{C}H_2$), 36.6 (<u>C</u>H), 14 $(CO_2CH_2\underline{C}H_3)_2$; HRMS found , 269.1507. $C_{13}H_{21}N_2O_4$ requires $[M+NH_4]^+$, 269.1501

Diethyl-2-[(2-bromopropen-2-yl)[3-carbonitrile)-3-cyclopentenyl]]propanedioate 4.- *The diester* (**3**) (500mg, 1.99 mmoles) was added to a stirred solution of potassium hydride (460mg, 4 mmoles)

in THF (30ml) at room temperature. After one hour HMPA (0.7ml, 4 mmoles) and 2,3-dibromopropene (0.75ml, 7.25 mmoles) were added and the reaction mixture stirred at room temperature for a further two hours. The reaction mixture was poured into aqueous hydrochloric acid (50ml, 5%) and ether (50ml) and the aqueous layer was extracted with ether (3 x 50ml). The organic layers were combined, washed with saturated sodium bicarbonate solution (6 x 50ml) and water (3 x 20ml) and dried over sodium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by chromatography using petrol : ether (10 : 1) as eluant to give *the bromide* (**4**) (561mg, 78%) as a pale yellow oil ; ν_{max} ($CHCl_3$) 2980, 2220, 1725 and 1625 cm^{-1}; δ_H (360 MHz) 6.5 (1H, m, J 2.4, C<u>H</u>), 5.65 (1H, d, J 1.75), 5.6 (1H, d, J 1.75) 4.2 (4H, m, $(CO_2C\underline{H}_2)_2$), 3.2 (1H, m, J 6.8 and 2.6, C<u>H</u>), 3.1 (2H, s, $C\underline{H}_2$), 2.75, (4H, m), 1.25 (6H, m, $(C\underline{H}_3)_2$); δ_C.(67.5 MHz); 169.2 (<u>C</u>O), 147.2 (<u>C</u>H), 126.5 (<u>C</u>Br), 122.2 (CBr<u>C</u>H_2), 116 (<u>C</u>N), 113.1 (<u>C</u>CN), 61.6 $(CO_2C\underline{H}_2)_2$, 59.7 <u>C</u>(CO_2CH_2), 44.3 (CBr<u>C</u>H_2), 38.6 (<u>C</u>H), 36.4 (<u>C</u>H_2), 35.7 (<u>C</u>H_2), 13.8 ($(CH_3)_2$); HRMS found 387.0926 $C_{16}H_{24}N_2O_4Br$ requires $[M+NH_4]^+$, 387.0919

endo-Diethyl(6-carbonitrile)(4-methylene)bicyclo[3.2.1]-2,2-dicarboxylate **5**.- Tri-*n*-butyltin hydride (216mg, 0.74 mmoles) was added dropwise to a stirred refluxing solution of *the diester* (**4**) (254mg, 0.68 mmoles) AIBN (15mg, 0.0915 mmoles) in benzene (30ml) and heated at reflux for two hours. The mixture was allowed to cool to room temperature and the solvent was removed " in vacuo " to give the crude product. The crude material was dissolved in ethyl acetate (5ml) and water (5ml) and stirred with potassium fluoride (100mg, 1.06 mmoles) for forty eight hours. The solution was filtered and the aqueous layer extracted with ethyl acetate (3 x 20ml). The organic layers were combined, washed with water (3 x 15ml) and dried over sodium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by chromatography using petrol : ether (6 : 1) as eluant to give *the diester* (**5**) (73mg, 37%) as a pale yellow oil ; ν_{max} (CH_2Cl_2) 3050, 2980, 2230 and 1725 cm^{-1}; δ_H (360 MHz) 4.98 (1H, t), 4.9 (1H, t), 4.2 (4H, m, $(CO_2C\underline{H}_2)_2$), 3.0 (4H, m), 2.55 (1H, dt, J 16 and 2.5), 2.4 (1H, m), 2.05, (1H, dd), 1.6 (2H, m, $C\underline{H}_2$), 1.2 (6H, m, $(CO_2CH_3)_2$); δ_H (360 MHz, C_6D_6); 5.15 (1H, t), 5.0 (1H, t), 4.2 (4H, c), 3.5, (1H, d), 3.25 (1H, t), 3.1 (1H, dt, J 16 and 2.5), 2.6 (1H, t), 2.3 (2H, c), 2.05, (1H, m), 1.7 (1H, d), 1.2 (1H, dt, J 12.5 and 4.8), 1.1 (6H, m); δC.(67.5 MHz); 169.9 (<u>C</u>O), 169.8 (<u>C</u>O), 142.5 (<u>C</u>CH_2), 120.6 (CH<u>C</u>N), 112.6 (<u>C</u>H_2), 61.4 $((CO_2\underline{C}H_2)_2)$, 58.6 (<u>C</u>$(CO_2CH_2CH_3)$), 47, (<u>C</u>H) 39 (<u>C</u>H), 35.7 (<u>C</u>H_2), 32.8 (<u>C</u>H_2), 31.3 (<u>C</u>H_2), 30.05 (<u>C</u>H), 13.8 (<u>C</u>$H_3)_2$;



Irradiation studies (C_6D_6)

Irradiation (ppm)	Effect
1.2, (H_{8a})	1.7, m, (H_{8b}); 2.6, d, (J = 5.3, H_5); 5.15, d, (J = 6.9, H_1);
1.7, (H_{8b})	1.2, m, (H_{8a});
2.05, (H_{7a})	3.25, d, (J = 5.2, H_1);
2.6, (H_5)	1.2, dd, (J = 12.5, H_{8a})
3.1, (H_{3a})	5.15, d, (J = 5.2, H_{13a}); 5.0, d, (H_{13b}); 3.5, s, (H_{3b})

nOe: irradiation at 5.0 (H_{13b}) led to n.O.e enhancement at 5.15 (H_{13a}) and 2.6, (H_5, 7%)

HRMS found, 309.1821. $C_{16}H_{25}N_2O_4$ requires $[M+NH_4]^+$, 309.1814

α-(2-Bromopropen-2-yl)-3-cyclohexen-1-methanol 10- 2,3-dibromopropene (5ml, 0.048 moles) was added to a mixture of 1,2,5,6-tetrahydrobenzaldehyde (2ml, 0.017 moles), powdered tin (3.0g, 0.025moles) in ether (32ml) and water (32ml) and hydrobromic acid (5 drops) at room temperature. The reaction mixture was then stirred at room temperature overnight and the poured into aqueous hydrochloric acid solution (150ml, 50%). The organic layer was separated and the aqueous layer was extracted with ether (3 x 100ml). The organic layers were combined and neutralised with saturated sodium bicarbonate solution and washed with water (2 x 50ml) and dried over magnesium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by bulb to bulb distillation (200°C, 0.5mm Hg) to give *the bromide* **10** (3.13g, 79%) as an inseparable mixture of diastereoisomers ; ν_{max} (CH_2Cl_2) 3600, 3020, 2920 and 1660 cm^{-1}; δ_H (270 MHz) 5.7 (3H, m), 5.6 (1H, s), 3.7 (1H, m, C<u>H</u>OH), 2.5 (2H, m, C<u>H</u>$_2$), 1.2-2.2 (8H, methylene envelope) δ_C (67.5 MHz); 131.37 (<u>C</u>Br), 127.33 (<u>C</u>H), 126.95 (<u>C</u>H), 126.23 (<u>C</u>H), 125.95 (<u>C</u>H), 119.75 (C(Br)<u>C</u>H$_2$), 119.65 (C(Br)<u>C</u>H$_2$), 72.39 (<u>C</u>HOH) 72.36 (<u>C</u>HOH), 46.65 (<u>C</u>H$_2$), 39.02 (CH(OH)<u>C</u>H), 38.77 (CH(OH)<u>C</u>H), 28.04 (CH_2), 26.32 (CH_2), 25.44 (CH_2), 25.28 (CH_2), 25.25 (CH_2), 24.2 (CH_2); HRMS found 248.0653. $C_{10}H_{19}BrNO$ requires $[M+NH_4]^+$ 248.0650

α-(2-Propenyl)-3-cyclohexen-1-methanol 11.- Allyl bromide (2.3ml, 26 mmoles) was added to a mixture of 1,2,5,6-tetrahydrobenzaldehyde (1ml, 8.5 mmoles), powdered tin (1.62g, 13.6 mmoles) in ether (15ml), water (15ml) and hydrobromic acid (5 drops) at room temperature. The reaction mixture was stirred at room temperature overnight and then poured into aqueous hydrochloric acid (100ml, 50%). The organic layer was then separated and the aqueous layer extracted with ether (3 x 50ml). The organic layers were combined and neutralised with saturated sodium bicarbonate solution and washed with brine (3 x 50ml) and dried over magnesium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by chromatography using petrol : ether (10 : 1 then 6 : 1) as eluant to give *the bromide* **11** (1.248g, 96%) as an inseparable mixture of diastereoisomers ν_{max} (CH_2Cl_2) 3600, 3020, 2900 and 1640 cm^{-1}; δ_H (270 MHz) 5.6-6.0 (3H, m), 5.1 (2H, m), 3.5 (1H, m, C<u>H</u>OH), 2.35 (1H, m,), 1.6 (8H, methylene envelope), 1.3 (1H,m) δ_C (67.5 MHz); 135.38 (<u>C</u>H), 135.23 (<u>C</u>H), 127.41 (<u>C</u>H), 126.95 (<u>C</u>H), 126.5 (<u>C</u>H), 126.14 (<u>C</u>H), 118.32 (<u>C</u>H$_2$), 118.13 (<u>C</u>H$_2$), 74.28 (<u>C</u>HOH), 74.16 (<u>C</u>HOH), 39.23 (CH(OH)<u>C</u>H), 39.13 (<u>C</u>H$_2$), 39.04 (<u>C</u>H$_2$), 39.02 (CH(OH)<u>C</u>H), 28.06 (<u>C</u>H$_2$), 26.6 (<u>C</u>H$_2$), 25.44 (<u>C</u>H$_2$), 25.38 (<u>C</u>H$_2$), 25.32 (<u>C</u>H$_2$), 24.43 (<u>C</u>H$_2$); HRMS found 170.1546. $C_{10}H_{20}NO$ requires $[M+NH_4]^+$, 170.1545

3-Methyl-1,2,3,3a,6,7,7a-hexahydro-1H-inden-1-ol 12.- Tri-*n*-butyltin chloride (150µl, 0.55 mmoles) was added to a stirred refluxing solution of *the bromide* **10** (1.269g, 5.5 mmoles), sodium cyanoborohydride (690mg, 10.9 mmoles), AIBN (90mg, 0.5 mmoles) in t-butanol (110ml) and allowed to stir at reflux. Further additions of AIBN (50mg, 0.3 mmoles) were added every twelve hours until the reaction was complete after three days. The mixture was allowed to cool to room temperature and poured into ether (200ml) and water (100ml). The organic layer was separated and the aqueous layer was extracted with ether (3 x 100ml). The organic layers were combined and washed with aqueous ammonia solution (3 x 100ml), brine (3 x 100ml) and water (3 x 100ml) and dried over magnesium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by chromatography using petrol : ether (60 : 1, 50 ; 1 then 30 : 1) as eluant to give first *the alcohol* **11** (172mg, 20%) then *the indenol* **12** (365mg, 43%)

both as inseparable mixtures of diastereoisomers. 12 ν_{max} (CH_2Cl_2) 3600, 3020, 2930 and 1645 cm-1; δ_H (270 MHz) 5.6 (2H, m), 4.6 (1H, t, OH), 3.9 (1H, m, CHOH), 1.2-2.8 (9H, methylene envelope), 0.9 (3H, m) ; HRMS found 152.1189. $C_{10}H_{16}O$ requires [M]+, 152.1171. Isolated 11 exhibited identical spectral details with those given.

[α and β] -3-Methyl -2,3,3a,6,7,7a-hexahydro-1H-inden-1-one 13- Pyridinium dichromate (1.8g, 5.17 mmoles) was added to a stirred solution of *the indenol* **12** (528mg, 3.47 mmoles) in dichloromethane (15ml) and stirred at room temperature overnight. Petrol (30ml) was added and the reaction mixture was filtered and the filtrate was washed with portions of ether (250ml total). The organic layers were combined and the solvent was removed " in vacuo " to give the crude product. Purification was carried out by chromatography using petrol : ether (50 : 1, 40 : 1 then 20 : 1) as eluant to give *the indenone* **13** (256mg, 49%) as an inseparable mixture of diastereoisomers ν_{max} (CH_2Cl_2) 3020, 2960 and 1730cm^{-1}; δ_H (360 MHz) 5.75 (2H, m), 2.4 (2H, dd, J 7.5), 2.2 (1H, dt, J 7.5), 2.1 (2H, m), 1.9 (2H, m), 1.7 (2H, q, J 6.2), 1.15 (3H, m, J 6.9, CH_3); δ_C (67.5 MHz); (CO) not found 130.97 (CH), 128.24 (CH) , 128.13 (CH), 124.98 (CH), 49.75 (COCH), 45.93 (COCH), 45.62 (CH_2CO), 44.03 (CH_2CO), 43.65 (CHCHCH), 40.4 (CHCHCH), 35.8 (CHCHCH), 33.83 (CHCHCH), 22.84 (CH_2), 21.54 (CH_2), 20.61 (CH_2), 20.31 (CH_2), 19.67 (CH_3), 16.2(CH_3); HRMS found 150.1037 $C_{10}H_{14}O$ requires [M]$^+$, 150.1045

α-(2-propynyl)-3-cyclohexene-1-methanol 14.- Propargyl bromide (7ml, 62.8 mmoles) was added dropwise to magnesium turnings (1.32g, 54.3 mmoles) and mercuric chloride (56mg, 0.2 mmoles) in ether (100ml) so as to maintain a steady reflux. After the addition was complete the reaction mixture was allowed to cool to room temperature and stirred at room temperature for a further one hour. 1,2,5,6-tetrahydrobenzaldehyde (1.99g, 18 mmoles) was added dropwise to the reaction mixture and after the addition was complete the reaction was stirred at room temperature for one hour. The mixture was poured into saturated ammonium chloride solution (20ml) and the aqueous layer extracted with ether (3 x 50ml). The organic layers were combined, washed with saturated sodium bicarbonate solution (6 x 50ml), water (3 x 50ml) and dried over magnesium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by bulb to bulb distillation (125°C, 0.5mmHg) to give *the alcohol* **14** (2.1g, 77%) as an inseparable mixture of diastereoisomers ν_{max} (CH_2Cl_2) 3600, 3300, 3020, 2920, 2120 and 1610 cm^{-1}; δ_H (270 MHz) 5.6 (2H, s), 5.1 (2H, m), 3.4 (1H, m, CHOH), 1.2 (9H, methylene envelope) δ_C (67.5 MHz); 127.42 (CH), 126.79 (CH), 126.18 (CH), 125.69 (CH), 81.21 (CH), 81.07 (CH), 73.41 (CHOH), 73.28 (CHOH), 70.96 (CH_2CCH), 70.82 (CH_2CCH), 38.58 (CH(OH)CH), 38.36 (CH(OH)CH), 27.88 (CH_2), 26.52 (CH_2), 25.23 (CH_2), 25.06 (CH_2), 24.81 (CH_2), 24.25 (CH_2); HRMS found 160.1394. $C_{10}H_{18}NO$ requires [M+NH_4]$^+$, 168.1388

[[(1-(3-Cyclohexenyl)]-3-butynyloxy](1,1-dimethylethyl)dimethylsilane 15.- t-Butyldimethylsilyl chloride (2g, 13.2 mmoles) was added to a stirred solution of *the alcohol* **14** (1.016g, 6.77 mmoles), imidazole (553mg, 8 mmoles) and N,N-dimethylaminopyridine (82mg, 0.67 mmoles) in DMF (3ml) and heated at 60°c overnight. The reaction mixture was allowed to cool to room temperature and poured into pentane (10ml), then extracted with pentane (3 x 10ml). The pentane layers were combined and washed with copper sulphate solution (3 x 10ml), brine (3 x 10ml), water (3 x 10ml) and dried over magnesium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by bulb to bulb distillation (220°c, 1.5mmHg) to give *the silane* **15** (1.369g, 76%) as an inseparable

mixture of diastereoisomers. ν_{max} (CH_2Cl_2) 3300, 3020, 2920, 2120 and 1650 cm^{-1}; δ_H (270 MHz) 5.7 (2H, s), 3.7 (1H, m, C<u>H</u>OSi), 2.4 (2H, m, C<u>H</u>$_2$), 1.2-1.7 (8H, methylene envelope), 0.9 (9H, m, C<u>H</u>$_3$), 0.1 (6H, m, C<u>H</u>$_3$); HRMS found, 265.1988. $C_{16}H_{29}OSi$ requires $[M+H]^+$, 264.1988.

6-[(3-Cyclohexenyl)[[(1,1-dimethylethyl)dimethylsilyl]oxy]]-3-hexyn-2-one 16.- n-Butyllithium (1.43ml, 2.3 mmoles) was added to a stirred cold solution (-40°C) of *the silane* **15** in THF (2ml) and stirred for five minutes. The resulting yellow solution was added *via* a canula to a stirred cold solution (-40°C) of acetyl chloride (0.3ml, 4.2 mmoles) in THF (3ml) and allowed to warm to room temperature. Saturated ammonium chloride solution (10ml) was added and the mixture was extracted with ether (3 x 10ml), brine (3 x 10ml), water (3 x 10ml) and dried over magnesium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. An initial separation was carried out by chromatography using petrol as eluant to give *the silane* **15** (11mg, 22%) and then the crude product. Purification was carried out by bulb to bulb distillation (150°C, 0.1mm Hg) to give *the yneone* **16** (157mg, 26.8%) as an inseparable mixture of diastereoisomers. ν_{max} (CH_2Cl_2) 3020, 2940, 2220 and 1675 cm^{-1}; δ_H (270 MHz) 5.7 (2H, s), 3.7 (1H, m, C<u>H</u>OSi), 2.6 (2H, m, C<u>H</u>$_2$), 2.5 (3H, s), 1.2-2.2 (7H, methylene envelope), 0.9 (9H, d, C<u>H</u>$_3$), 0.1 (6H, dd, C<u>H</u>$_3$); δ_C (67.5 MHz); 184.78 (<u>C</u>O), 127.24 (<u>C</u>H), 126.92 (<u>C</u>H), 126.42 (<u>C</u>H), 126.15 (<u>C</u>H), 91.45 ($CH_2\underline{C}CCO$), 91.35 ($CH_2\underline{C}CCO$), 82.76 ($CH_2C\underline{C}CO$), 73.8 (<u>C</u>HOSi), 73.74 (<u>C</u>HOSi), 39.03 (CH(OSi)<u>C</u>H) , 38.84 (CH(OSi)<u>C</u>H), 32.83 (<u>C</u>H$_3$), 27.88 (<u>C</u>H$_2$), 25.9 (<u>C</u>H$_3$), 25.76 (<u>C</u>H$_2$), 25.65 (<u>C</u>H$_2$), 25.53 (<u>C</u>H$_2$), 25.47 (<u>C</u>H$_2$), 25.36 (<u>C</u>H$_2$), 25.14 (<u>C</u>H$_2$), 23.82 (<u>C</u>H$_2$), 18.13 (<u>C</u>H$_3$), -4.30 (<u>C</u>H$_3$), -4.56 (<u>C</u>H$_3$); HRMS found 307.2093 $C_{18}H_{31}O_2Si$ requires $[M+H]^+$, 307.2093

(z)-6-[(3-Cyclohexenyl)[[(1,1-dimethylethyl)dimethylsilyl]oxy]]-4-iodo-3-hexen-2-one 17a and (e)-6-[(3-cyclohexenyl)[[(1,1-dimethylethyl)dimethylsilyl]oxy]]-4-iodo-3-hexen-2-one 17b.- Iodotrimethylsilane (0.9ml, 6.14 mmoles) was added dropwise to a stirred cold solution (-78°C) of *the yneone* **16** (1.324g, 4.3 mmoles) in dichloromethane (15ml) and stirred for thirty minutes at -78°C. Water (10ml) was added and the reaction was allowed to warm to room temperature. The aqueous layer was extracted with dichloromethane (3 x 10ml) and the organic layers were combined and washed with saturated sodium bicarbonate solution (2 x 10ml), saturated sodium thiosulphate solution (2 x 10ml), brine (2 x 10ml) and dried over magnesium sulphate. Filtration and removal of the solvent " in vacuo" gave the crude product. Initial separation of the two isomers was carried out by chromatography using petrol : ether (30 : 1, 20 : 1 then 10 : 1) as eluant. Further purification of each of the isomers was carried out separately by chromatography using petrol : ether (20 : 1) as eluant to give *the iodide* **17a** (589mg, 31.5%) and *the iodide* **17b** (502mg, 26.9%) both as inseparable mixtures of diastereoisomers.

z-Isomer 17a ν_{max} (CH_2Cl_2) 3020, 2920, 1690 and 1590 cm^{-1}; δ_H (270 MHz) 6.8 (1H, s, COC<u>H</u>), 5.6 (2H, s, C<u>H</u>), 4.0 (1H, m, C<u>H</u>OSi), 2.8 (2H, m, C(I)C<u>H</u>$_2$), 2.3 (3H, s, C(O)C<u>H</u>$_3$), 1.2-2.1 (7H, methylene envelope), 0.9 (9H, s, C<u>H</u>$_3$), 0.1 (6H, d, C<u>H</u>$_3$); δ_C (67.5 MHz); 195.53 (<u>C</u>O), 195.48 (<u>C</u>O), 133.36 (CO<u>C</u>H), 133.22 (CO<u>C</u>H), 127.26 (<u>C</u>H), 126.72 (<u>C</u>H), 126.65 (<u>C</u>H), 126.36 (<u>C</u>H), 114.89 (<u>C</u>I), 114.79 (<u>C</u>I), 74.31 (<u>C</u>HOSi), 74.17 (<u>C</u>HOSi), 52.17 (C(I)<u>C</u>H$_2$), 51.92 (C(I)<u>C</u>H$_2$), 39.43 (CH(OSi)<u>C</u>H), 39.24 (CH(OSi)<u>C</u>H), 31.67 (CO<u>C</u>H$_3$), 27.38 (<u>C</u>H$_2$), 26.47 (<u>C</u>H$_2$), 26.02 (CO<u>C</u>H$_3$), 25.91 (<u>C</u>H$_2$), 25.82 (<u>C</u>H$_2$), 25.07 (<u>C</u>H$_2$), 24.35 (<u>C</u>H$_2$), 18.22 (<u>C</u>H$_3$), -3.81 (<u>C</u>H$_3$), -3.86 (<u>C</u>H$_3$), -4.23 (<u>C</u>H$_3$), -4.36 (<u>C</u>H$_3$); HRMS found 435.1216 $C_{18}H_{32}O_2ISi$ requires $[M+H]^+$, 435.1216

e-Isomer 17b ν_{max} (CH_2Cl_2) 3020, 2920, 1700, 1665 and 1595 cm^{-1}; δ_H (270 MHz) 7.1 (1H, s, COC<u>H</u>), 5.6 (2H, s, C<u>H</u>), 4.0 (1H, m, C<u>H</u>OSi), 3.3 (2H, m, ClC<u>H</u>$_2$), 2.1 (3H, s, COC<u>H</u>$_3$), 1.2-2.0 (7H,

methylene envelope), 0.9 (9H, s, $C\underline{H}_3$), 0.1 (6H, d, $C\underline{H}_3$); δ_C (67.5 MHz); 195.35 (<u>C</u>O), 195.27 (<u>C</u>O), 140.69 (CO<u>C</u>H), 127.13 (<u>C</u>H), 126.98 (<u>C</u>H), 126.9 (<u>C</u>H), 126.67 (<u>C</u>I), 126.45 (<u>C</u>I), 76.47 (<u>C</u>HOSi), 76.14 (<u>C</u>HOSi), 45.03 ($C\underline{H}_2$), 44.96 ($C\underline{H}_2$), 39.37 (CH(OSi)<u>C</u>H), 39.25 (CH(OSi)<u>C</u>H), 31.36 ($\underline{C}H_3$), 31.32 ($\underline{C}H_3$), 28.14 ($\underline{C}H_2$), 26.04 ($\underline{C}H_3$), 25.98 ($\underline{C}H_3$), 25.73 ($\underline{C}H_2$), 25.62 ($\underline{C}H_2$), 23.72 ($\underline{C}H_2$), 18.2 ($\underline{C}H_3$), -3.72 ($\underline{C}H_3$), -3.78 ($\underline{C}H_3$), 4.37 ($\underline{C}H_3$); HRMS found 435.1216 $C_{18}H_{32}O_2ISi$ requires $[M+H]^+$, 435.1216

(e)-4-Bromo-6-[(3-cyclohexenyl)[[(1,1-dimethylethyl)dimethylsilyl]oxy]]-3-hexen-2-one 17c and (z)-4-Bromo-6-[(3-cyclohexenyl)[[(1,1-dimethylethyl)dimethylsilyl]oxy]]-3-hexen-2-one 17d.- Bromotrimethylsilane (0.2ml, 1.5 mmoles) was added to a stirred solution of *the yneone* **16** (410mg, 1.34 mmoles) in dichloromethane (5ml) at -78°C. After thirty minutes further bromotrimethylsilane (0.4ml, 3 mmoles) was added and allowed to warm to 0°C. The mixture was cooled to -78°C and bromotrimethylsilane (0.4ml, 3 mmoles) was added, after a further ten minutes water was added and the reaction mixture was allowed to warm to room temperature.The aqueous layer was extracted with dichloromethane (3 x 10ml) and the organic layers were combined and washed with saturated sodium bicarbonate solution (2 x 10ml), saturated sodium thiosulphate solution (2 x 10ml), brine (2 x 10ml) and dried over sodium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by chromatography using petrol : ether (100 : 1) as eluant to give *the bromide* **17c** (156mg, 30%) and *the bromide* **17d** (140mg, 27%) both as inseparable mixtures of diastereoisomers.

e-Isomer 17c ν_{max} (CH_2Cl_2) 3020, 2920, 1695, and 1600 cm^{-1}; δ_H (360 MHz) 6.75 (1H, s, COC<u>H</u>), 5.6 (2H, m, C<u>H</u>), 4.0 (1H, m, C<u>H</u>OSi), 3.3 (1H, m), 3.1 (1H, m) 2.2 (3H, s, $COC\underline{H}_3$), 2.0 (4H, m), 1.6 (2H, m), 1.2 (1H, m), 0.9 (9H, s, $C\underline{H}_3$), 0.1 (6H, d, $C\underline{H}_3$); δ_C (67.5 MHz); 195.25 (<u>C</u>O), 146.75 (<u>C</u>Br), 146.702 (<u>C</u>Br), 132.16 (CO<u>C</u>H), 127.11 (<u>C</u>H), 126.93 (<u>C</u>H), 126.68 (<u>C</u>H), 74,95 (<u>C</u>HOSi), 74.82 (<u>C</u>HOSi), 42.21 (C(Br)$C\underline{H}_2$), 42.12 (C(Br)$C\underline{H}_2$), 39.57 (CH(OSi)<u>C</u>H), 39.50 (CH(OSi)<u>C</u>H), 31.79 ($\underline{C}H_3CO$), 27.88 ($\underline{C}H_2$), 25.95 ($\underline{C}H_3$), 25.58 ($\underline{C}H_2$), 25.5 ($\underline{C}H_2$), 23.8 ($\underline{C}H_2$), 18.2 ($C\underline{H}_3$), -4.07 ($C\underline{H}_3$), -4.45 ($C\underline{H}_3$); m/z (CI, NH_3) $[M+NH_4]^+$ 404.9.

z-Isomer 17d ν_{max} (CH_2Cl_2) 3020, 2920, 1700, 1675 and 1620 cm^{-1}; δ_H (360 MHz) 6.6 (1H, d, J 2.9, C<u>H</u>), 5.65 (2H, s, COC<u>H</u>), 4.0 (1H, m, C<u>H</u>OSi), 2.65 (2H, t, J 5.3, C(Br)$C\underline{H}_2$) 2.28 (3H, $\underline{C}H_3CO$), 1.8 (4H, m), 1.6 (2H, m), 1.2 (1H, m), 0.85 (9H, s, $C\underline{H}_3$), 0.1 (6H, d, $C\underline{H}_3$); δ_C (67.5 MHz); 195.95 (<u>C</u>O), 195.92 (<u>C</u>O), 135.77 (<u>C</u>Br), 129.64 (CO<u>C</u>H), 129.52 (CO<u>C</u>H), 127.16 (<u>C</u>H), 127 (<u>C</u>H), 126.57 (<u>C</u>H), 126.27 (<u>C</u>H), 73.6 (<u>C</u>HOSi), 73.4 (<u>C</u>HOSi), 48.33 (C(Br)$\underline{C}H_2$), 48.02 (C(Br)$\underline{C}H_2$), 39.58 (CH(OSi)<u>C</u>H), 39.42 (CH(OSi)<u>C</u>H), 31.43 ($\underline{C}H_3CO$), 27.2 ($\underline{C}H_2$), 26 ($\underline{C}H_2$), 25.94 ($\underline{C}H_3$), 25.84 ($\underline{C}H_2$), 25.74 ($\underline{C}H_2$), 24.98 ($\underline{C}H_2$), 24.3 ($\underline{C}H_2$), 18.16 ($\underline{C}H_3$), -4.2 ($\underline{C}H_3$), -4.39 ($\underline{C}H_3$); m/z (CI, NH_3) $[M+NH_4]^+$ 404.9.

3-[3-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-1,2,3,3a,4,5,7a-hexahydro-1H-indenyl]propan-2-one 18.- Tri-*n*-butyltin hydride (0.25ml, 0.93 mmoles) was added to a stirred refluxing solution of *the iodide* **17a** (400mg, 0.92 mmoles) and AIBN (15mg, 0.09 mmoles) in benzene (65ml) and the reaction stirred at reflux for one hour. After allowing to cool to room temperature the solvent was removed " in vacuo " to give the crude product. Initial separation was carried out by chromatography using petrol : ether (100 : 1, 90 : 1, 80 : 1, 70 : 1, 60 : 1 then 50 :1) as eluant. Purification was carried out by chromatography (60 : 1 then 10 : 1) as eluant to give *the ketone* **18** (221mg, 78%) as an inseparable mixture of diastereoisomers.

Alternative procedure: Tri-*n*-butyltin hydride (90 µl, 0.33 mmoles) was added to a stirred refluxing

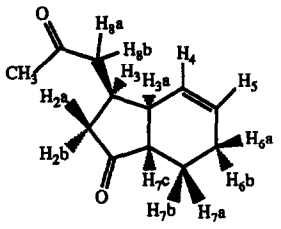
solution of *the iodide* **17b** (140mg, 0.33 mmoles), AIBN (10mg, 0.06 mmoles) in benzene (25ml) and stirred at reflux for one hour. The mixture was allowed to cool to room temperature and the solvent was removed " in vacuo " to give the crude product. The crude material was dissolved in ethyl acetate (5ml) and water (2ml) and stirred with potassium fluoride(100mg, 1.06 mmoles) for two hours. The solution was filtered and the filtrate washed with ethyl acetate (100ml total). The organic layers were combined and dried over sodium sulphate. Filtration and removal of the solvent " in vacuo " gave the crude product. Purification was carried out by chromatography using petrol : ether (100 : 1) as eluant to give *the ketone* **18** (73mg, 61%) as an inseparable mixture of diastereoisomers.

This procedure was used to cyclise *the bromide* **17d** (83mg, 0.215 mmoles) using (7 l, 0.26 mmoles) of tri-*n*-butyltin hydride at reflux overnight to give *the ketone* **18** (35mg, 53%) as an inseparable mixture of diastereoisomers.

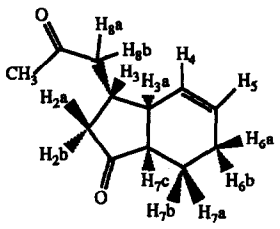
This procedure was used to cyclise *the bromide* **17c** (100mg, 0.26 mmoles) using (75 l, 0.28 mmoles) of tri-*n*-butyltin hydride at reflux over two days to give *the ketone* **18** (52mg, 65%) as an inseparable mixture of diastereoisomers.

ν_{max} (CH_2Cl_2) 3020, 2920 and 1710 cm^{-1}; δ_H (270 MHz) 5.6 (2H, m, C<u>H</u>), 3.8 (1H, m, C<u>H</u>(OSi), 2.2 (2H, m), 2.1 (3H, s) 1.2-2.0 (9H, methylene envelope), 0.9 (9H, m) 0.1 (6H, s, C<u>H</u>$_3$); δ_C (67.5 MHz); CO not found 129.86 (<u>C</u>H), 129.26 (<u>C</u>H), 129.06 (<u>C</u>H), 128.01 (<u>C</u>H), 126.68 (<u>C</u>H), 126.62 (<u>C</u>H), 126.38 (<u>C</u>H), 77.29 (<u>C</u>HOSi), 76.21 (<u>C</u>HOSi), 74.26 (<u>C</u>H), 50.31 (<u>C</u>H$_2$), 50.11 (<u>C</u>H$_2$), 48.02 (<u>C</u>H$_2$), 47.42 (<u>C</u>H), 47.06 (<u>C</u>H$_2$), 46.06 (<u>C</u>H), 43.53 (<u>C</u>H), 42.88 (<u>C</u>H), 42.67 (<u>C</u>H), 41.79 (<u>C</u>H), 41.36 (<u>C</u>H$_2$), 40.88 (<u>C</u>H$_2$), 39.8 (<u>C</u>H$_2$), 39.66 (<u>C</u>H), 39.24 (<u>C</u>H), 38.61 (<u>C</u>H), 38.29 (<u>C</u>H), 35.61 (<u>C</u>H), 33.26 (<u>C</u>H), 30.47 (<u>C</u>H$_3$CO), 30.21 (<u>C</u>H$_3$CO), 30.07 (<u>C</u>H$_3$CO), 25.98 (<u>C</u>H$_3$), 24.71 (<u>C</u>H$_2$), 24.02 (<u>C</u>H$_2$), 23.36 (<u>C</u>H$_2$), 23.32 (<u>C</u>H$_2$), 23.2 (<u>C</u>H$_2$), 22.38 (<u>C</u>H$_2$), 20.38 (<u>C</u>H$_2$), 19.43 (<u>C</u>H$_2$), 18.29 (<u>C</u>H$_3$), 18.13 (<u>C</u>H$_3$), -4.47 (<u>C</u>H$_3$), -4.6 (<u>C</u>H$_3$), -4.86 (<u>C</u>H$_3$); HRMS found 309.2250 $C_{18}H_{33}O_2Si$ requires $[M+H]^+$, 309.2249

β-3-(2-Oxopropyl)-1,2,3,3a,6,7,7a-hexahydro-1H-inden-1-one 20 and α-3-(2-Oxopropyl)-1,2,3,3a,6,7,7a-hexahydro-1H-inden-1-one 21.- Aqueous hydrogen fluoride (0.5ml, 15 mmoles) was added dropwise to a stirred solution of *the ketone* **18** (85mg, 0.276 mmoles) in acetonitrile (5ml) at room temperature. As soon as the addition was complete the solution was neutralised with sodium bicarbonate. The reaction mixture was extracted with ether (5 x 10ml) and the organic layers were combined and dried over sodium sulphate. Removal of the solvent " in vacuo " and chromatography using petrol : ether (3 : 1, 2 : 1, 1 : 1 then 1 : 3) as eluant gave the crude *alcohol* **19** (39mg, 73%) which was used immediately. Pyridinium dichromate (481mg, 1,38 mmoles) was added to a stirred solution of the crude alcohol **19** (176mg, 0.9 mmoles) in dichloromethane (10ml) and the reaction mixture stirred at room temperature overnight. Petrol (10ml) was added and the reaction mixture was filtered and the filtrate was washed with portions of ether (200ml total). The solvent was removed " in vacuo " to give the crude product. Purification was carried out by chromatography using ether : petrol (3 : 1) as eluant to give first *the diketone* **20** (25mg, 14%) then a mixture of *the diketones* **20** and **21** (72mg, 41%) and then *the diketone* **21** (12mg, 7%).



20



21

β–Isomer-20 ν_{max} (CH_2Cl_2) 3020, 2915, 1735 and 1715 cm^{-1}; δ_H (360 MHz, C_6D_6) 5.9 (1H, m, J 2.7, C<u>H</u>, H_5), 5.5 (1H, m, J 11.6 and 1.25, C<u>H</u>, H_4), 2.85 (1H, m, J 3.0 and 2.8, C<u>H</u>,H_{3a}), 2.6 (1H, m, C<u>H</u>, H_3), 2.4 (1H, ddt, J 7.6 and 1.2, C<u>H</u>, H_{2b}), 2.35 (1H, m, C<u>H</u>, H_{7b}), 2.29 (1H, m, J 6.7, C<u>H</u>, H_{7c}), 2.25 (1H, dd, J 17.5 and 6.6, C<u>H</u>, H_8), 2.15 (1H, m, C<u>H</u>, H_{6a}), 2.05 (1H, q, J 17.4 and 7.8, C<u>H</u>, H_8), 1.9 (1H, m, C<u>H</u>, H_{6b}), 1.85 (3H, s, $COCH_3$), 1.75 (1H, dd, J 18.2 and 12.15, C<u>H</u>, H_{2a}), 1.6 (1H, m, C<u>H</u>, H_{7a}); δ_C (67.5 MHz); 219.5 (<u>C</u>O), 207.5 (<u>C</u>O), 131.8 (<u>C</u>H), 124.4 (<u>C</u>H), 49.1 (<u>C</u>H), 45.24 ($\underline{C}H_2$), 42 ($\underline{C}H_2$), 38.8 (<u>C</u>H), 34.24 (<u>C</u>H), 30.44 ($\underline{C}H_3CO$), 21.4 ($\underline{C}H_2$), 20.1 ($\underline{C}H_2$);

α-Isomer-21 ν_{max} (CH_2Cl_2) 3020, 2915, 1735 and 1715 cm^{-1}; δ_H (360 MHz) 5.7 (2H, m, C<u>H</u>, H4 and H5), 2.6 (1H, q, J 18.4 and 8,), 2.5 (1H, m, C<u>H</u>), 2.3 (1H, m, C<u>H</u>), 2.2 (1H, dd, J 17.25 and 6, C<u>H</u>), 1.85 (5H, m), 1.85-2.1 (3H, s, $COCH_3$), 1.7 (1H, m), 1.6 (1H, m); δ_C (67.5 MHz); 220 (<u>C</u>O), 207.4 (<u>C</u>O), 129.1 (<u>C</u>H), 127.4 (<u>C</u>H), 48.2 ($\underline{C}H_2$), 45.73 (<u>C</u>H), 43.5 ($\underline{C}H_2$), 41.5 (<u>C</u>H), 36.22 (<u>C</u>H), 30.44 ($\underline{C}H_2$), 22.62 ($\underline{C}H_2$), 20.4 ($\underline{C}H_2$);

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References and Notes

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