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Microwave-Mediated Sulfonium Ylide Cyclopropanation. Stereoselective Synthesis of Cyclopropa[c]pentalenes

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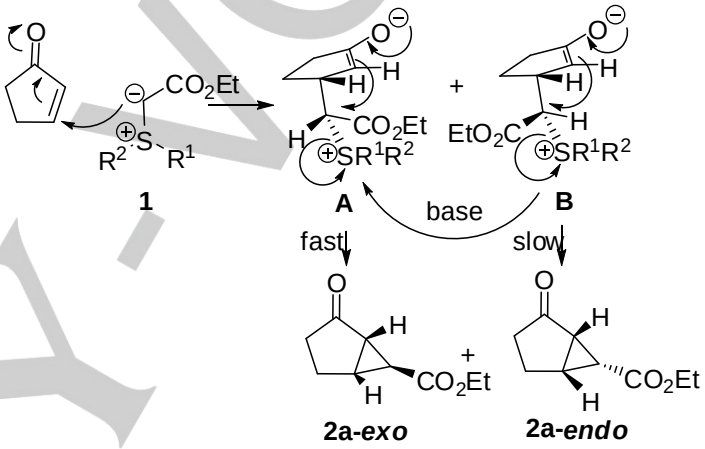
Abstract: Stereoselective sulfonium ylide cyclopropanation is a useful transformation due to the presence of this moiety in numerous bioactive compounds. The procedures described to date involve long reaction times and variable stereoselectivity outcomes. We show here that performing these reactions under MW mediation give excellent yields and selectivities after short reaction periods. The methodology is applied to different substrates including sterically hindered cyclopentenones, open chain unsaturated esters and pentalenones (Pauson-Khand products). From these latter substrates, highly connected cyclopropa[c]pentalenes were synthesized in good yields, including a precursor of natural product pentalenene.

Introduction

Cyclopropanes are found as a basic structural motif in naturally occurring compounds and in biologically active molecules. In addition, they can undergo many chemical transformations to give useful intermediates. The ylide cyclopropanation is one of the earliest developed and extensively studied synthetic procedures to build these structures. In particular sulfur ylides are important reagents useful for the preparation of cyclopropanes and epoxydes.[1] Chiral sulfur ylides have been used for the asymmetric version of this reaction.[2] The experimental procedures reported to date generally consist of the treatment of a sulfonium salt with a base (generally DBU) to form the ylide, followed by prolonged reaction times to produce the cycloaddition reaction. The mechanistic course for the cyclopropanation, starts with the initial attack of the sulfur ylide to the electrophilic center of the Michael acceptor forming a betaine which gives the final cyclopropane after an intramolecular nucleophilic displacement (Scheme 1).
Previously reported mechanistic studies show that in this stepwise reaction the formation of the first C-C bond is the rate determining step.[3] The stereoselectivity of the reaction is determined, however, in the second step. Following studies reported by Aggarwal's group, two intermediate betaines **A** and **B** would be formed in a 1:1 ratio after the nucleophilic addition. The cyclization of betaine **B** is slow whereas **A** cyclizes faster. Due to the presence of a base, an epimerization of **B** is possible to give **A** leading generally to high diastereoselectivities favoring the *exo* isomer.[4] This base-mediated epimerization is the responsible for a loss of enantioselectivity when using chiral sulfonium ylides, as the epimerization at the ester stereocenter ultimately leads to the opposite *exo*-enantiomer of the cyclopropane.[5]



Scheme 1. Mechanism of ylide cyclopropanation.

The general long reaction conditions are an important drawback and conventional heating is scarcely used as it may cause undesired side reactions. A convenient alternative to circumvent this problem would be the conduction of the cyclopropanation in a microwave (MW) reactor.[6] Advantages compared to the conventional heating would be the rapid access to high reaction temperatures and fast cooling at the end of the reaction, improved purity profiles, and practical issues as the accurate control of reaction parameters.
Herein we show the feasibility of performing the sulfonium ylide cyclopropanation reaction under MW mediation which proceeds with excellent yields and selectivities after short reaction periods. We show the application of this methodology to the synthesis of highly connected tricycles including a precursor of natural product pentalenene.

Results and Discussion

used 2-cyclopentenone as a model substrate in order to optimize the ratio of sulfonium salt, base, temperature and time (Table 1). This reaction has been previously reported using reaction times from 8h to more than 18h at rt or 30ºC giving yields going from 66-77%.[5,7] It was described under conventional heating at 100 ºC for 17 h giving 68% yield.[8] We monitorized by NMR the conversion into final product. Final yield

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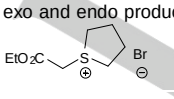
in pure product is shown. Among the different solvents used, (entries 1-4), only in DCM and chloroform did the reaction take place, giving the latter a better conversion and yield. Increasing the amount of salt and base (entry 5) only produced a marginal increment in conversion but lower yield. Raising the temperature allowed nearly or total conversions in 10 min achieving the best yields at 70 ºC (entry 6). These latter conditions were used with sulfonium salt 1b but the yield achieved was lower (entry 7). At higher temperatures, a possible decomposition of starting materials was deleterious for the efficiency of this process (entries 8-9). Reduction of the reaction time to 1 minute did not give good results (entry 10). The reactions carried out during 60 minutes did not improve the results of those performed in 10 minutes (entries 11-12). Thus, selected conditions were: 1.1 equiv of salt, 1.1 equiv of DBU, 70 ºC, 10 min (entry 6).

Table 1. Optimization of reaction conditions. Synthesis of **2a**.[a]

No.	Solvent	Temp. (ºC)	Reaction time (min.)[b]	Conversion (%) (*exo:endo*)[c]	Yield[d] 2a (%)
1	DCM	40	10	60 (18:1)	23
2	$CHCl_3$	40	10	80 (15:1)	60
3	Toluene	40	10	n.d.	n.d.
4	H_2O/DMSO	40	10	n.d.	n.d.
5	$CHCl_3$[e]	40	10	83 (15:1)	58
6	$CHCl_3$	70	10	95 (12:1)	80
7	$CHCl_3$[f]	70	10	93 (10:1)	69
8	$CHCl_3$	100	10	100 (8:1)	22
9	$CHCl_3$	150	10	n.d.	n.d.
10	$CHCl_3$	70	1	55 (11:1)	40
11	$CHCl_3$	70	60	95 (12:1)	81
12	$CHCl_3$	40	60	90 (15:1)	60

[a] Conditions: DBU (1.1 equiv), salt **1a** (EtO_2CCH_2-$S^+(CH_3)_2$, Br^-; 1.1 equiv). [b] Ylide formation 30 min rt. [c] Ratio calculated from ^{1}H-NMR spectra of the reaction crude. [d] Combined yield in pure exo and endo products. [e] DBU (2 equiv), **1a** (2 equiv). [f] Salt **1b** was used:



With the optimized conditions in hand we extended the reaction to other substrates isolating products **2b-f** and **4** (Figure 1). Good yields and *exo*-selectivities were achieved with products **2a-c**. On the other hand **2d-e** were isolated in poor yields and interestingly only as the *endo* isomers. The nucleophilic attack to the 3-methyl substituted cyclopentenone is sterically disfavoured which explains the low yield. In addition, the presence of the methyl group favors an intermediate of type **B** (Scheme 1), leading to the *endo* isomer. However this cyclopropanation reaction on 3-substituted unsaturated ketones is unprecedent to the best of our knowledge. Product **2f** was isolated upon reaction with a benzoyl-stabilized sulfonium ylide in excellent yield, only detecting the *exo* isomer in the reaction mixture.

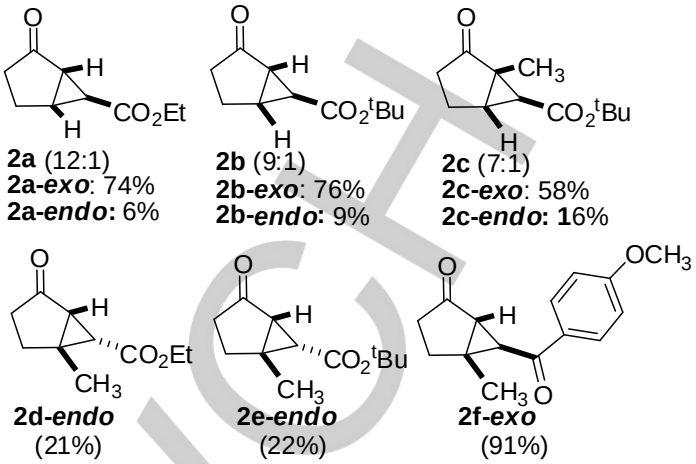
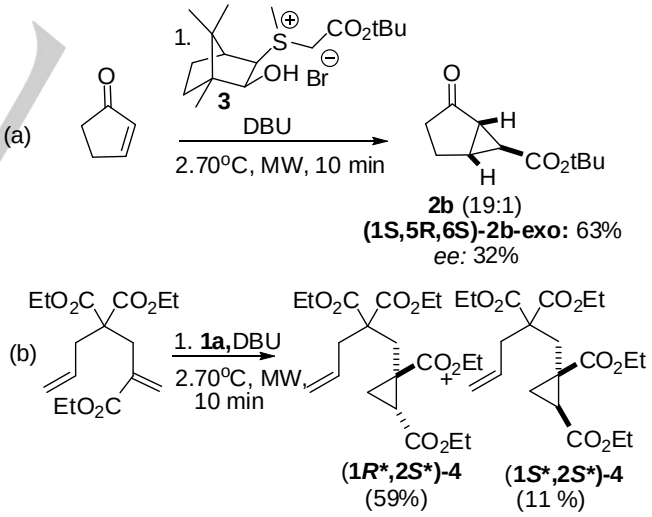


Figure 1. Cyclopropanation of 2-cyclopentenones.

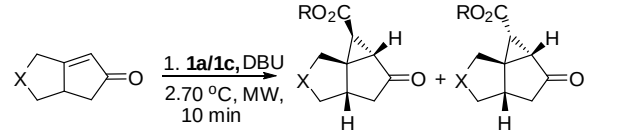
In order to show the possibility of using chiral sulfonium ylides derived from camphor auxiliaries, we submitted 2-cyclopentenone to a reaction with the ylide derived from **3** (Scheme 2a).[9] This reaction gave a crude mixture with a (19:1, *exo:endo*) ratio in product **2b**. The exo isomer was isolated with a 63% yield and with a moderate *ee* (32%).[10] In addition we prepared product **4** with excellent yield as a mixture of *cis:trans* isomers from an open chain substrate (Scheme 2b).



Scheme 2. Asymmetric synthesis of **2b** and synthesis of **4**.

We were interested in using this methodology for the synthesis of cyclopropa[c]pentalene systems as they are interesting highly compact structurally complex architectures. They can be used as synthetic intermediates for the synthesis of triquinane natural products. These are classic targets for total synthesis because

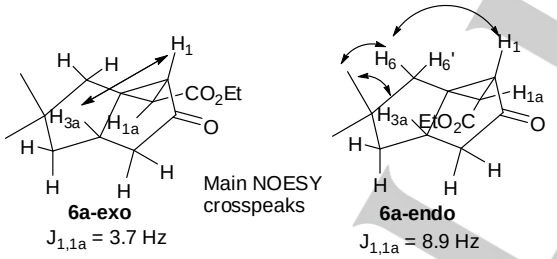
of their biological activity.[11] Thus, we prepared substrates **5a-c**, according to literature procedures, using the Pauson-Khand reaction.[12] The reaction of the substrates with ylides from salts **1a** and **1c** is summarized in Scheme 3. Two out of the four possible diastereoisomers were formed in the three reactions, corresponding to the *exo* and *endo* cyclopropanes as shown by the coupling constants between the cyclopropanic protons H1 and H1a (H5a and H6 for **6e-f**). This means a total diastereoselective initial nucleophilic attack. The relative stereochemistry was established through NOE cross peaks. Main increments are shown for isomers **6a**. The reactions proceeded with good global yields despite the highly compact structures obtained and the formation of a quaternary carbon in the reaction. A reaction under conventional heating was performed with **5a** (70 C heating for 18h) reaching a conversion of 45% and a total yield of 32% as a 1:1 mixture of isomers **6a**. Compounds **6a** have been used as intermediates in the total synthesis of pentalenene.[13]



5a: X = $C(CH_3)_2$
5b: X = $C(CO_2Et)_2$
5c: X = NTs

Yield:	exo	endo	ratio[a]
6a: R = Et, X = $C(CH_3)_2$	16%	16%	(1:1)[b]
6a: R = Et, X = $C(CH_3)_2$	31%	29%	(1:1)
6b: R = ^{t}Bu, X = $C(CH_3)_2$	29%	16%	(3:2)
6c: R = Et, X = $C(CO_2Et)_2$	42%	33%	(5:2)
6d: R = ^{t}Bu, X = $C(CO_2Et)_2$	38%	34%	(3:2)
6e: R = Et, X = NTs	60% in mixture		(3:1)
6f: R = ^{t}Bu, X = NTs	48% in mixture		(2:1)

[a] Calculated in the NMR spectra of the crude
[b] Under conventional heating, 18 h



Scheme 3. Synthesis of products **6**.

Conclusions

We describe herein a microwave-mediated procedure for the cyclopropanation of α,β-unsaturated ketones which reduces substantially the reaction time compared with previously reported results. This methodology is useful with different kinds of substrates. In particular we describe the synthesis of highly rigidified tricyclic compounds, including a precursor of pentalenene, an antibiotic produced by several species of Streptomyces, which has shown to be active against a large number of eukaryotic organisms. Using a microwave reactor provides greater control over reaction parameters, permitting a more efficient optimization of the reaction conditions.

Experimental Section

General: All reactions were carried out in a Biotage Initiator+ microwave reactor. Reaction progress was monitored using analytical thin-layer chromatography (TLC) on Merck silica gel 60 F-254 plate. Visualization was achieved by UV light (254 nm). NMR spectra were recorded on a Bruker spectrometer (400 MHz for ^{1}H, and 101 MHz for ^{13}C). Chemical shifts are reported in δ ppm referenced to chloroform-*d* (δ 7.26 for ^{1}H NMR and δ 77.00 for ^{13}C NMR). All the residues were purified by flash chromatography on silica gel. Bidimensional spectra (HMQC, HMBC, COSY, NOESY) were recorded for all compounds in order to carry out the assignation. Sulfonium salts were prepared following the procedures described in the literature.[14]

General procedure for the MW mediated cyclopropanation reaction: To a stirred solution of the corresponding salt (1.1 eq.) in $CHCl_3$ (1M) was added DBU (1.1 equiv). After 30 minutes, the corresponding substrate was added (1 equiv) and the reaction mixture was heated up to 70ºC through microwave irradiation during 10 min. The reaction mixture was then washed with HCl 1M (0.8ml/ equiv), water (2x0.8ml/ equiv) and brine (2x0.8ml/ equiv), dried over $MgSO_4$, filtered and concentrated under vacuum to give the desired compounds.

Ethyl 2-oxobicyclo[3.1.0]hexane-6-carboxylate, 2a: From 150 mg of cyclopent-2-enone (1.82 mmol) and 458.3 mg of salt **1a** (2 mmol), a crude mixture of isomeric cyclopropanes (*exo:endo*) was obtained (12:1). After chromatography (Hexane/AcOEt, 9:1), 228 mg (74% yield) of pure **2a-*exo*** and 18 mg (6%) of **2a-*endo***, both as white solids, were isolated. Using 510 mg of salt **1b** (2 mmol) gave a mixture of both isomers (*exo:endo* 10:1). After chromatography (Hexane/AcOEt, 9:1) 195 mg (63% yield) of pure **2a-*exo*** and 17 mg (6%) of **2a-*endo***, both as white solids, were isolated. Both isomers gave the same spectroscopical data as described previously.[5]

tert*-Butyl 2-oxobicyclo[3.1.0]hexane-6-carboxylate, 2b:** From 150 mg of cyclopent-2-enone (1.82 mmol) and 566.5 mg of salt **1c** (2 mmol), a crude mixture of isomeric (*exo:endo*) cyclopropanes was obtained (9:1). After chromatography (Hexane/AcOEt, 9:1), 271 mg (76% yield) of pure **2b-*exo and 30 mg (9%) of **2b-*endo***, both as white solids, were isolated. Both isomers gave the same spectroscopical data as described previously.[5]

tert*-Butyl 1-methyl-2-oxobicyclo[3.1.0]hexane-6-carboxylate, 2c.** From 150 mg of 2-methylcyclopentenone (1.56 mmol) and 488.24 mg of salt **1c** (1.71 mmol), a crude mixture of isomeric cyclopropanes was obtained (7:1). After chromatography (Hexane/AcOEt, 9:1), 190 mg (58% yield) of pure **2c-*exo (Rf: 0.31, Hexane/AcOEt, 9:1) and 52 mg (16%) of a 1:1 mixture of both isomers, both as colorless oils, were isolated. Major isomer showed a J_{trans} = 3.9 Hz between H6 and H5 so it was assigned as *exo*. **(1*S**,5*S**,6*S**)-2c-*exo***: IR: 2974, 2935, 2876, 1716 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.42 – 2.40 (m, 1H, CH_2CH), 2.15 – 2.00 (m, 4H, CH_2CH_2), 1.88 (d, *J* = 3.9 Hz, 1H, $CHCO_2$), 1.46 (s, 9H, $C(CH_3)_3$), 1.31 (s, 3H, CCH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 214.2 ($CH_2C=O$), 168.4 ($CO_2C(CH_3)_3$), 81.5 ($C(CH_3)_3$), 39.4 (CCH_3), 33.1 (CH_2CH), 31.8 ($CH_2C=O$), 31.2 ($CHCO_2$), 28.2 ($C(CH_3)_3$), 21.4 (CH_2CH), 8.1 (CCH_3). Anal. Calcd. for $C_{12}H_{18}O_3$ (210.27 g/mol): C, 68.5; H, 8.6 %. Found: C, 68.7; H, 8.4 %. **(1S*,5S*,6R*)-2c-*endo*** (data taken from a diastereomeric enriched mixture): IR: 2974, 2935, 2876, 1716 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.38 (m, 1H, CH_2CH), 2.34 – 2.19 (m, 4H, $CH_2C=O$ + CH_2CHH), 2.04 (dd,

J = 9.3, 7.8 Hz, 1H, CH_2CHH), 1.44 (s, 9H, $C(CH_3)_3$), 1.29 (s, 3H, CCH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 214.2 ($CH_2C=O$), 168.9 (CO_2 $C(CH_3)_3$), 81.5 ($C(CH_3)_3$), 39.2 (CCH_3), 37.6 ($CH_2C=O$), 36.3 (CH_2CH), 31.2 ($CHCO_2$), 28.1 ($C(CH_3)_3$), 19.00 (CH_2CH), 15.9 (CCH_3).

(1*R,5*R**,6*S**)-tert-Butyl 1-methyl-4-oxobicyclo[3.1.0]hexane-6-carboxylate, 2d-*endo*:** From 150 mg of 3-methylcyclopentenone (1.56 mmol) and 488.24 mg of salt **1c** (1.71 mmol), after chromatography (Hexane/AcOEt, 9:1), 69 mg (21% yield) of pure product (Rf: 0.10, Hexane/AcOEt, 9:1). The product showed a J_{cis} = 9.4 Hz between H6 and H5 so it was assigned as *endo* (1*S**,5*S**,6*S**). IR: 2978, 2923, 1728 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 2.44 – 2.25 (m, 2H, $CH_2C=O$), 2.25 – 2.16 (m, 1H, $CHHCCH_3$), 2.10 (d, *J* = 9.4 Hz, 1H, $CHCO_2$), 2.07 – 1.99 (m, 1H, $CHHCCH_3$), 1.97 (d, *J* = 9.4 Hz, 1H, $CHC=O$), 1.44 (s, 9H, $C(CH_3)_3$), 1.41 (s, 3H, CCH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 213.4 ($CH_2C=O$), 168.7 ($CHCO_2$), 81.7 ($C(CH_3)_3$), 40.8 ($CHC=O$), 38.4 ($CH_2C=O$), 38.1 (CCH_3), 36.6 ($CHCO_2$), 28.1 ($C(CH_3)_3$)), 26.7 (CCH_2), 23.0 (CCH_3). Anal. Calcd. for $C_{12}H_{18}O_3$ (210.27 g/mol): C, 68.5; H, 8.6 %. Found: C, 68.7; H, 8.8 %.

(1*R,5*R**,6*S**)-Ethyl 1-methyl-4-oxobicyclo[3.1.0]hexane-6-carboxylate, 2e-*endo*:** From 150 mg of 3-methylcyclopentenone (1.56 mmol) and 395 mg of salt **1a** (1.71 mmol), after chromatography (Hexane/AcOEt, 6:1), 59 mg (22% yield) of pure product (Rf: 0.10, Hexane/AcOEt, 6:1). The product showed a J_{cis} = 9.5 Hz between H6 and H5 so it was assigned as (1*S**,5*S**,6*S**). ^1H NMR (400 MHz, $CDCl_3$) δ 4.18 – 4.11 (m, 2H, CH_2CH_3), 2.49 – 2.38 (m, 1H, $CHHC=O$), 2.38 – 2.28 (m, 1H, $CHHC=O$), 2.26 – 2.18 (m, 1H, $CHHC$), 2.16 (d, *J* = 9.5 Hz, 1H, $CHCO_2$), 2.10 – 2.01 (m, 1H, $CHHC$), 2.05 (d, *J* = 9.5 Hz, 1H, $CHC=O$), 1.44 (s, 3H, CCH_3), 1.29 – 1.24 (t, *J* = 7.1 Hz, 3H, CH_2CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 213.3 ($CH_2C=O$), 169.6 (CO_2CH_2), 61.2 (CO_2CH_2), 41.1 ($CHC=O$), 38.6 ($CH_2C=O$), 38.5 (CCH_3), 35.3 ($CHCO_2$), 26.8 (CH_2C), 23.0 (CCH_3), 14.2 (CH_2CH_3). Anal. Calcd. for $C_{10}H_{14}O_3$ (182.22 g/mol): C, 65.9; H, 7.7 %. Found: C, 65.6; H, 7.5 %.

(1S*,5R*,6S*)-6-(4-methoxybenzoyl)bicyclo[3.1.0]hexan-2-one, 2f-*exo*: From 150 mg of cyclopentenone (1.83 mmol) and 586.2 mg of salt **1d** (2.03 mmol), after chromatography (Hexane/AcOEt, 9:1), 355 mg (91% yield) of pure product were obtained (Rf: 0.05, Hexane/AcOEt, 9:1). The product showed a J_{trans} = 2.5 Hz between H6 and H1 and a J_{trans} = 3.4 Hz between H6 and H5 so it was assigned as (1*S**,5*S**,6*S**). IR: 2949, 2911, 2840, 1727, 1660, 1590 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 7.99 – 7.94 (m, 2H, $CHCC=O$), 6.99 – 6.94 (m, 2H, $CHCOCH_3$), 3.89 (s, 3H, OCH_3), 2.95 (dd, *J* = 3.4, 2.5 Hz, 1H, $CHC=OAr$), 2.66 (td, *J* = 5.2, 3.4 Hz, 1H, CH_2CH), 2.48 (dd, *J* = 5.5, 2.5 Hz, 1H, $CH_2C=OCH$), 2.39 – 2.25 (m, 1H, $CHHCH$), 2.24 – 2.18 (m, 3H, $CHHCH$ + $CH_2C=O$). ^{13}C NMR (101 MHz, $CDCl_3$) δ 212.6 ($CH_2C=O$), 193.6 ($CHC=OC$), 163.8 (Ar), 130.5 (Ar), 129.9 (Ar), 113.9 (Ar), 55.5 (OCH_3), 38.2 ($CH_2C=OCH$), 32.5 ($CH_2C=O$), 31.7 (CH_2CH), 29.8 ($CHC=OAr$), 22.8 (CH_2CH). Anal. Calcd. for $C_{14}H_{14}O_3$ (230.26 g/mol): C, 73.0; H, 6.1 %. Found: C, 72.8; H, 6.4 %.

Diethyl 1-(2,2-bis(ethoxycarbonyl)pent-4-en-1-yl)cyclopropane-1,2-dicarboxylate, 4: From 300 mg of triethyl hepta-1,6-diene-2,4,4-tricarboxylate[15] (0.96 mmol) and 260 mg of salt **1a** (1.01 mmol), a crude mixture of isomeric cyclopropanes was obtained (6:1). After chromatography (Hexane/AcOEt, 19:1), 224 mg (59% yield) of pure major isomer (Rf: 0.11, Hexane/AcOEt, 19:1) and 42 mg (11%) of minor isomer (Rf: 0.03, Hexane/AcOEt, 19:1), both as colorless oils, were isolated. Major isomer showed a ^4J = 1.2 Hz between H3' and CH_2 and H3' showed a J_{cis} = 8.7 Hz with H2. NOESY spectrum showed cross peaks of H3 with H2 (strong) and with both CH_2 protons (weak). Thus, this isomer was assigned as (1*R**, 2*S**). IR: 2984, 2915, 1730, 1640 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 5.79 (ddt, *J* = 17.3, 10.2, 7.2 Hz, 1H, $CH_2=CH$), 5.11 – 5.03 (m, 2H, CH_2CH), 4.26 – 4.00 (m, 8H, CO_2CH_2), 2.73 (dt, *J* = 14.2, 1.3 Hz, 1H, $CH_2CH=CH_2$), 2.71 (dd, *J* = 15.2, 1.2 Hz, 1H, $CCHHC$), 2.58 (ddt, *J* = 14.2, 7.2, 1.3 Hz, 1H, $CH_2CH=CH_2$), 2.42 (d, *J* = 15.2 Hz, 1H, $CCHHC$), 2.06 (dd, *J* = 8.7, 6.7 Hz, 1H, $CHCO_2$), 1.76 (ddd, *J* = 8.7, 4.8, 1.2 Hz, 1H, $CHHCHCO_2$), 1.53 (dd, *J* = 6.7, 4.8 Hz, 1H, $CHHCHCO_2$), 1.31 – 1.21 (m, 12H, CH_2CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.2 ($CO_2CH_2CH_3$), 171.0 ($CO_2CH_2CH_3$), 170.8($CO_2CH_2CH_3$), 169.9 ($CO_2CH_2CH_3$), 132.9 ($CH_2=CH$), 118.7 ($CH_2=CH$), 61.4 ($CO_2CH_2CH_3$), 61.2 ($CO_2CH_2CH_3$), 61.2 ($CO_2CH_2CH_3$), 61.1 ($CO_2CH_2CH_3$), 57.2 ($C=OCC=O$), 39.5 ($CH_2C=CH_2$), 29.7 (CH_2CCH_2), 29.3 (CCH_2C), 28.3 (CCH), 18.0 (CH_2CHCO_2), 14.2 ($CO_2CH_2CH_3$), 14.0 ($CO_2CH_2CH_3$), 13.9 ($CO_2CH_2CH_3$), 13.8 ($CO_2CH_2CH_3$). Anal. Calcd. for $C_{20}H_{30}O_8$ (398.45 g/mol): C, 60.3; H, 7.6 %. Found: C, 60.1; H, 7.3 %. Minor isomer was assigned as (1S*,2S*): IR: 2984, 2940, 2911, 1730, 1635 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 5.66 (ddt, *J* = 17.3, 10.2, 7.3 Hz, 1H, $CH_2=CH$), 5.14 – 5.02 (m, 2H, $CH_2=CH$), 4.26 – 3.96 (m, 8H, $CO_2CH_2CH_3$), 2.89 (d, *J* = 15.1 Hz, 1H, $CHHC$), 2.73 (qd, *J* = 14.6, 7.3 Hz, 2H, $CCH_2CH=CH_2$), 1.86 (d, *J* = 15.0 Hz, 1H, $CCHHC$), 1.84 – 1.79 (m, 2H, $CHCO_2$ + $CHHCHCO_2$), 1.30 – 1.17 (m, 13H, $CHHCHCO_2$ + $CO_2CH_2CH_3$). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.6 ($CO_2CH_2CH_3$), 170.5 ($CO_2CH_2CH_3$), 170.2 ($CO_2CH_2CH_3$), 170.0 ($CO_2CH_2CH_3$), 132.5 ($CH_2=CH$), 119.1 ($CH_2=CH$), 61.4 ($CO_2CH_2CH_3$), 61.4 ($CO_2CH_2CH_3$), 61.1 ($CO_2CH_2CH_3$), 60.9 ($CO_2CH_2CH_3$), 57.4 (CO_2CCO_2), 37.9 (CCH_2C), 37.3 ($CCH_2CH=CH_2$), 31.0 (CH_2CCH), 28.1 (CCH), 18.1 (CH_2CHCO_2), 14.2 ($CO_2CH_2CH_3$), 13.9 ($CO_2CH_2CH_3$), 13.9 ($CO_2CH_2CH_3$), 13.9 ($CO_2CH_2CH_3$). Anal. Calcd. for $C_{20}H_{30}O_8$ (398.45 g/mol): C, 60.3; H, 7.6 %. Found: C, 60.4; H, 7.4 %.

Ethyl 5,5-dimethyl-2-oxooctahydrocyclopropa[c]pentalene-1-carboxylate, 6a: From 150 mg of **5a**[12] (1.00 mmol) and 252.05 mg of salt **1a** (1.10 mmol), a crude mixture of isomeric cyclopropanes was obtained (1:1). After chromatography (Hexane/AcOEt, 14:1), 73 mg (31% yield) of a colorless oil (Rf: 0.22; Hexane/AcOEt, 14:1) was obtained. This isomer was assigned as **6a-*exo*** (1S*, 1aS*, 3aS*, 6aS*) based on: Coupling constant of J_{trans} = 3.7 Hz between H1a and H1. NOESY spectrum showed cross peaks of H1a with H3a. 68 mg, (29%) of another fraction containing a (13:1) mixture of the second isomer and the starting material was isolated Rf: 0.18 (Hexane/AcOEt, 14:1). Data for second isomer are given from this mixture. Configuration was assigned as **6a-*endo*** (1R*, 1aS*, 3aS*, 6aS*) based on: Coupling constant of J_{cis} = 8.9 Hz between H1a and H1. NOESY spectrum showed cross peaks of H1a with one H6 which showed cross peaks with 1 methyl group. This very same methyl group showed cross peaks with H3a. In addition, H1 showed cross peaks with the other H6 proton. This agrees with the configuration presented according to 3D models. **6a-*exo*.** IR: 2956, 2936, 2867, 1726 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 4.24 – 4.07 (m, 2H, CH_2CH_3), 2.73 – 2.64 (m, 1H, CH_2CHCH_2), 2.23 (dd, *J* = 18.7, 7.8 Hz, 1H, $CHHC=O$), 2.21 (d, *J* = 3.1 Hz, 1H, $CHCO_2$), 2.17 (d, *J* = 3.1 Hz, 1H, $CHCHC=O$), 2.02 (dt, *J* = 19.1, 1.5 Hz, 1H, $CHHC=O$), 1.91 – 1.79 (m, 3H, CCH_2C + $CCHHCH$), 1.32 – 1.24 (m, 1H, $CCHHCH$), 1.27 (t, *J* = 7.1 Hz, 3H, CH_2CH_3), 1.12 (s, 3H, CCH_3), 1.09 (s, 3H, CCH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 212.1 ($CH_2C=O$), 169.5 (CO_2CH_2), 61.1 (CH_2CH_3), 48.6 (CCH_2CH), 47.7 (CH_2CCH), 42.0 ($CHCO_2$), 41.7 (CCH_2C), 40.7 (CH_2CHCH_2), 40.0 ($CH_2C=O$), 39.0 ($C(CH_3)_2$), 31.0 ($CHCHC=O$), 30.2 ($C(CH_3)_2$), 29.9 ($C(CH_3)_2$), 14.2 (CH_2CH_3). Anal. Calcd. for $C_{14}H_{20}O_3$ (236.31 g/mol): C, 71.2; H, 8.5 %. Found: C, 71.4; H, 8.8 %. **6a-*endo*:** IR: 2956, 2936, 2867, 1726 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 4.21 – 4.07 (m, 2H, CH_2CH_3), 2.79 – 2.67 (m, 2H, $CHHC=O$ + CH_2CHCH_2), 2.38 (d, *J* = 9.0 Hz, 1H, $CHCHC=O$), 2.15 – 2.06 (m, 1H, $CHHC=O$), 2.12 (d, *J* = 8.8 Hz, 1H, $CHCO_2$), 1.98 (ddd, *J* = 12.5, 8.0, 1.3 Hz, 1H, $CCHHCH$), 1.86 (d, *J* = 13.3 Hz, 1H, $CCHHC$), 1.64 (d, *J* = 13.3 Hz, 1H, $CCHHC$), 1.41 (dd, *J* = 12.7, 8.4 Hz, 1H, $CCHHCH$), 1.27 (t, *J* = 7.1 Hz, 3H, CH_2CH_3), 1.12 (s, 3H, $C(CH_3)_2$), 1.09 (s, 3H, $C(CH_3)_2$). ^{13}C NMR (101 MHz, $CDCl_3$) δ 213.7 ($CH_2C=O$), 170.1 (CO_2CH_2), 61.2 (CH_2CH_3), 49.8 (CH_2CCH), 49.7 (CCH_2CH), 47.7 ($CH_2C=O$), 46.2 (CCH_2C), 41.9

(*C*HCO$_2$), 40.6 (*C*(CH$_3$)$_2$), 37.7 (CH$_2$*C*HCH$_2$), 33.8 (CH*C*HC=O), 29.0 (C(*C*H$_3$)$_2$), 28.6 (C(*C*H$_3$)$_2$), 14.2 (CH$_2$*C*H$_3$).

tert*-Butyl 5,5-dimethyl-2-oxooctahydrocyclopropa[c]pentalene-1-carboxylate, 6b:** From 150 mg of **5a**[12] (1.00 mmol) and 311.54 mg of salt **1c** (1.10 mmol), a crude mixture of isomeric cyclopropanes was obtained (3:2). After chromatography (Hexane/AcOEt, 14:1), 77 mg (29% yield) of isomer as a colorless oil (Rf: 0.32; Hexane/AcOEt, 14:1). This isomer was assigned as **6b-*exo (1S*, 1aS*, 3aS*, 6aS*) based on: Coupling constant of J_{trans} = 2.9 Hz between H1a and H1. NOESY spectrum showed cross peaks of H1a with H3a. 42 mg, (16%) of another fraction containing a (1:13 *exo:endo*) mixture Rf: 0.28 (Hexane/AcOEt, 14:1). Data for second isomer are given from this mixture. Configuration was assigned as **6b-*endo*** (1R*, 1aS*, 3aS*, 6aS*) based on: Coupling constant of J_{cis} = 9.0 Hz between H1a and H1. NOESY spectrum showed cross peaks of H1a with one H6 which showed cross peaks with 1 methyl group. This same methyl group showed cross peaks with H3a. In addition, H1 showed cross peaks with the other H6 proton. This agrees with the conformation presented according to 3D models. **6b-*exo:*** IR: 2956, 2867, 2258, 1722 cm^{-1}. ^{1}H NMR (400 MHz, CDCl$_3$) δ 2.73 – 2.64 (m, 1H, CH$_2$*C*HCH$_2$), 2.21 (dd, *J* = 19.3, 7.8 Hz, 1H, CH*H*C=O), 2.16 (d, *J* = 2.9 Hz, 1H, *C*HCO$_2$), 2.09 (d, *J* = 2.9 Hz, 1H, CH*C*HC=O), 1.99 (dt, *J* = 19.2, 1.4 Hz, 1H, CH*H*C=O), 1.89 – 1.78 (m, 3H, CCH$_2$C + CCH*H*CH), 1.45 (s, 9H, C(*CH$_3$*)$_3$), 1.27 (dd, *J* = 12.6, 11.2 Hz, 1H, CCH*H*CH), 1.12 (s, 3H, C(C*H$_3$*)$_2$), 1.09 (s, 3H, C(C*H$_3$*)$_2$). ^{13}C NMR (101 MHz, CDCl$_3$) δ 212.5 (CH$_2$*C*=*O*), 168.5 (*C*O$_2$CH$_2$), 81.6 (*C*(CH$_3$)$_3$), 48.6 (C*C*H$_2$CH), 47.6 (CH$_2$*C*(CH)$_3$), 41.9 (*C*HCO$_2$), 41.8 (C*C*H$_2$C), 40.7 (CH$_2$*C*HCH$_2$), 40.0 (*C*H$_2$C=O), 38.9 (*C*(CH$_3$)$_2$), 32.1 (CH*C*HC=O), 30.3 (C(*CH$_3$*)$_2$), 29.9 (C(*CH$_3$*)$_2$), 28.1 (C(*CH$_3$*)$_3$). Anal. Calcd. for C$_{14}$H$_{24}$O$_3$ (264.36 g/mol): C, 72.7; H, 9.2 %. Found: C, 73.0; H, 9.4 %. **6b-*endo***: IR: 2956, 2867, 2258, 1722 cm^{-1}. ^{1}H NMR (400 MHz, CDCl$_3$) δ 2.74 – 2.64 (m, 2H, CH$_2$*C*HCH$_2$ + CH*H*C=O), 2.33 (d, *J* = 9.0 Hz, 1H, CHC*H*C=O), 2.16 – 2.01 (m, 1H, CH*H*C=O), 2.05 (d, *J* = 9.1 Hz, 1H, C*H*CO$_2$), 1.97 (ddd, *J* = 12.5, 7.9, 1.2 Hz, 1H, CCH*H*CH), 1.84 (d, *J* = 12.8 Hz, 1H, CCH*H*C), 1.62 (d, *J* = 13.3 Hz, 1H, CH*H*C), 1.44 (s, 9H, C(C*H$_3$*)$_3$), 1.40 (dd, *J* = 12.7, 8.4 Hz, 1H, CCH*H*CH), 1.11 (s, 3H, C(C*H$_3$*)$_2$), 1.09 (s, 3H, C(C*H$_3$*)$_2$). ^{13}C NMR (101 MHz, CDCl$_3$) δ 213.8 (CH$_2$*C*=*O*), 169.2 (*C*O$_2$CH$_2$), 81.7 (*C*(CH$_3$)$_3$), 49.7 (C*C*H$_2$CH), 49.5 (CH$_2$*C*CH), 47.7 (*C*H$_2$C=O), 46.2 (C*C*H$_2$C), 41.6 (*C*HCO$_2$), 40.6 (*C*(CH$_3$)$_2$), 37.6 (CH$_2$*C*HCH$_2$), 35.3 (CH*C*HC=O), 29.0 (C(*CH$_3$*)$_2$), 28.5 (C(*CH$_3$*)$_2$), 28.1 (C(*CH$_3$*)$_3$).

Triethyl 2-oxohexahydrocyclopropa[c]pentalene-1,5,5(6H)-tricarboxylate, 6c: From 350 mg of diethyl **5b**[12] (1.31 mmol) and 330 mg of salt **1a** (1.44 mmol), a crude mixture of isomeric cyclopropanes was obtained (5:2). After chromatography (Hexane/AcOEt, 6:1), 195 mg (42% yield) of a colorless oil (Rf: 0.20; Hexane/AcOEt, 6:1) were obtained. This isomer was assigned as **6c-*exo*** (1S*, 1aS*, 3aS*, 6aS*) based on: Coupling constant of J_{trans} = 3.0 Hz between H1a and H1 and analogy with compound **6a-*exo***. 157 mg, (33%) of another fraction containing a (1:3) mixture of isomers was isolated Rf: 0.15 (Hexane/AcOEt, 6:1). Data for minor isomer are given from this mixture. Configuration was assigned as **6c-*endo*** (1R*, 1aS*, 3aS*,6aS*) based on: Coupling constant of J_{cis} = 9.3 Hz between H1a and H1 and a strong NOE cross peak in the NOESY of these two protons as well as analogy with **6a-*endo*. 6c-*exo*:** IR: 2978, 2939, 1724 cm^{-1}. ^{1}H NMR (400 MHz, CDCl$_3$) δ 4.23 – 4.08 (m, 6H, C*H$_2$*CH$_3$), 2.72 (d, *J* = 15.1 Hz, 1H, CCH*H*C), 2.68 – 2.58 (m, 2H, CCH*H*CH + CH$_2$*C*HCH$_2$), 2.63 (d, *J* = 15.2 Hz, 1H, CCH*H*C), 2.30 – 2.19 (m, 1H, CH*H*C=O), 2.23 (d, *J* = 3.0 Hz, 1H, C*H*CO$_2$), 2.17 (d, *J* = 3.0 Hz, 1H, CHC*H*C=O), 2.15 – 2.05 (m, 1H, CH*H*C=O), 2.00 – 1.91 (m, 1H, CCH*H*CH), 1.24 (m, 9H, CH$_2$C*H$_3$*). ^{13}C NMR (101 MHz, CDCl$_3$) δ 210.3 (CH$_2$*C*=*O*), 171.6 (C(*C*O$_2$CH$_2$)$_2$), 171.1 (C(*C*O$_2$CH$_2$)$_2$), 168.9 (CHC*O*$_2$CH$_2$), 61.8 (C(CO$_2$C*H*$_2$)$_2$), 61.3 (CHCO$_2$C*H*$_2$), 59.6 (*C*(CO$_2$CH$_2$)$_2$), 46.0 (CH$_2$*C*CH), 41.0 (*C*HCO$_2$), 40.8 (C*C*H$_2$CH), 40.0 (CH$_2$*C*HCH$_2$), 39.7 (*C*H$_2$C=O), 34.6 (C*C*H$_2$C), 30.0 (CH*C*HC=O), 14.2 (CHCO$_2$CH$_2$*C*H$_3$), 13.9 (C(CO$_2$CH$_2$*C*H$_3$)$_2$). Anal. Calcd. for C$_{18}$H$_{24}$O$_7$ (352.38 g/mol): C, 61.4; H, 6.9 %. Found: C, 61.2; H, 6.7 %. **6c-*endo*:** IR: 2978, 2939, 1724 cm^{-1}. ^{1}H NMR (400 MHz, CDCl$_3$) δ 4.26 – 4.07 (m, 6H, C*H$_2$*CH$_3$), 2.83 – 2.70 (m, 4H, CH$_2$C*H*CH$_2$ + CCH*H*CH + CH*H*C=O + CH*H*C), 2.43 (d, *J* = 9.3 Hz, 1H, CHC*H*C=O), 2.32 – 2.21 (m, 3H, CCH*H*CH + CH*H*C=O + CH*H*C), 2.13 (d, *J* = 9.1 Hz, 1H, C*H*CO$_2$), 1.30 – 1.22 (m, 9H, CH$_2$C*H$_3$*). ^{13}C NMR (101 MHz, CDCl$_3$) δ 212.0 (CH$_2$*C*=*O*), 171.1 (C*C*O$_2$), 171.0 (C*C*O$_2$), 169.6 (CH*C*O$_2$), 61.9 (C(CO$_2$*C*H$_2$)$_2$), 61.8 (CHCO$_2$*C*H$_2$), 60.7 (*C*(CO$_2$CH$_2$)$_2$), 48.1 (CH$_2$*C*CH), 47.3 (C*C*H$_2$C or C*C*H$_2$CH or CH*C*H$_2$C=O), 41.8 (C*C*H$_2$C or C*C*H$_2$CH or CH*C*H$_2$C=O), 41.4 (CH*C*HC=O), 38.8 (C*C*H$_2$C or C*C*H$_2$CH or CH*C*H$_2$C=O), 36.7 (CH$_2$*C*HCH$_2$), 32.2 (*C*HCO$_2$), (CHCO$_2$CH$_2$*C*H$_3$), 14.0 (C(CO$_2$CH$_2$*C*H$_3$)$_2$).

1-*tert*-Butyl 5,5-diethyl 2-oxohexahydrocyclopropa [c]pentalene-1,5,5(6H)-tricarboxylate, 6d: From 350 mg of diethyl **5b**[12] (1.31 mmol) and 408 mg of salt **1c** (1.44 mmol), a crude mixture of isomeric cyclopropanes was obtained (3:2). After chromatography (Hexane/AcOEt, 9:1), 179 mg (38% yield) of a colorless oil (Rf: 0.13; Hexane/AcOEt, 9:1) were obtained. This isomer was assigned as **6d-*exo*** (1S*, 1aS*,3aS*,6aS*) based on: Coupling constant of J_{trans} = 3.0 Hz between H1a and H1. NOE cross peak in the NOESY of H3a with H1a and analogy with compound **6b-*exo***. 171 mg, (34% yield) of another fraction containing a (1:3) mixture of isomers was isolated Rf: 0.11 (Hexane/AcOEt, 9:1). Data for minor isomer are given from this mixture. Configuration was assigned as **6d-*endo*** (1R*, 1aS*,3aS*,6aS*) based on: Coupling constant of J_{cis} = 9.2 Hz between H1a and H1 and a strong NOE cross peak in the NOESY of these two protons. A cross peaks between H1a with H3a suggests this configuration. **6d-*exo***: IR: 2980, 2936, 1726 cm^{-1}. ^{1}H NMR (400 MHz, CDCl$_3$) δ 4.28 – 4.15 (m, 4H, C*H$_2$*CH$_3$), 2.75 (d, *J* = 15.1 Hz, 1H, CH*H*C), 2.70 – 2.59 (m, 2H, CCH*H*CH + CH$_2$*C*HCH$_2$), 2.62 (d, *J* = 14.7 Hz, 1H, CH*H*C), 2.28 – 2.19 (m, 1H, CH*H*C=O), 2.20 (d, *J* = 3.0 Hz, 1H, C*H*CO$_2$), 2.14 – 2.07 (m, 1H, CH*H*C=O), 2.11 (d, *J* = 3.0 Hz, 1H, CHC*H*C=O), 2.04 – 1.95 (m, 1H, CCH*H*CH), 1.46 (s, 9H, C(C*H$_3$*)$_3$), 1.26 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H$_3$*), 1.24 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H$_3$*). ^{13}C NMR (101 MHz, CDCl$_3$) δ 210.7 (CH$_2$*C*=*O*), 171.7 (*C*O$_2$CH$_2$), 171.2 (*C*O$_2$CH$_2$), 168.0 (*C*O$_2$C), 82.0 (*C*(CH$_3$)$_3$), 61.8 (CO$_2$*C*H$_2$), 61.8 (CO$_2$*C*H$_2$), 59.7 (*C*(CO$_2$CH$_2$CH$_3$)$_2$), 45.9 (CH$_2$*C*(CH)$_2$), 41.0 (*C*HCO$_2$), 40.9 (C*C*H$_2$CH), 40.0 (CH$_2$*C*HCH$_2$), 39.8 (*C*H$_2$C=O), 34.6 (C*C*H$_2$C), 31.2 (CH*C*HC=O), 28.1 (C(*CH$_3$*)$_3$), 14.0 (CH$_2$*C*H$_3$). Anal. Calcd. for C$_{20}$H$_{28}$O$_7$ (380.43 g/mol): C, 63.1; H, 7.4 %. Found: C, 62.9; H, 7.1 %. **6d-*endo***: IR: 2980, 2936, 1726. ^{1}H NMR (400 MHz, CDCl$_3$) δ 4.23 – 4.15 (m, 4H, C*H$_2$*CH$_3$), 2.78 – 2.58 (m, 3H, CCH*H*CH + CH*H*C=O + CH$_2$C*H*CH$_2$), 2.76 (d, *J* = 13.9 Hz, 1H, CH*H*C), 2.37 (d, *J* = 9.2 Hz, 1H, CHC*H*C=O), 2.30 – 2.18 (m, 2H, + CCH*H*CH + CH*H*C=O), 2.28 (d, *J* = 13.7 Hz, 1H, CH*H*C), 2.04 (d, *J* = 9.3 Hz, 1H, C*H*CO$_2$), 1.43 (s, 9H, C(C*H$_3$*)$_3$), 1.26 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H$_3$*), 1.24 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H$_3$*). ^{13}C NMR (101 MHz, CDCl$_3$) δ 212.0 (CH$_2$*C*=*O*), 171.2 (*C*O$_2$CH$_2$), 171.0 (*C*O$_2$CH$_2$), 168.6 (*C*O$_2$C), 82.0 (*C*(CH$_3$)$_3$), 61.9 (CO$_2$*C*H$_2$), 61.7 (CO$_2$*C*H$_2$), 60.8 (*C*(CO$_2$CH$_2$CH$_3$)$_2$), 47.8 (CH$_2$*C*(CH)$_2$), 47.3 (C*C*H$_2$CH), 41.9 (*C*H$_2$C=O), 41.1 (*C*HCO$_2$), 38.9 (C*C*H$_2$C), 36.5 (CH$_2$*C*HCH$_2$), 33.5 (CH*C*HC=O), 28.0 (C(*CH$_3$*)$_3$), 14.0 (CH$_2$*C*H$_3$).

Ethyl 5-oxo-2-tosyloctahydrocyclopropa[1,5]cyclopenta[1,2-c]pyrrole-6-carboxylate, 6e: From 500 mg of **5c**[12] (1.98 mmol) and 500 mg of salt **1a** (2.18 mmol), a crude mixture of isomeric cyclopropanes was obtained (3:1). After chromatography (Hexane/AcOEt, 3:2), 431 mg (60% yield) of a colorless oil (Rf: 0.27; Hexane/AcOEt, 3:2), was isolated containing a 7:2 mixture of two diasteromers. Major isomer was assigned as **6e-*exo*** (3aS*, 5aS*,6S*,6aR*) based on: Coupling constant of J_{trans} = 2.9 Hz between H5a and H6, NOE cross peak in the NOESY between H3a and H5a and the absence of any cross peak between H3a and H6. Minor isomer was assigned as **6e-*endo*** (3aS*, 5aS*,6R*,6aR*) based on: Coupling constant of J_{cis} = 12.4 Hz between H5a and H6.IR: 2951, 2932,

2864, 1726 cm^{-1}. Data given from the mixture. **6e-*exo*:** ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.1 Hz, 2H, C*H*CSO$_2$), 7.31 (d, *J* = 8.1 Hz, 2H, CH$_3$CC*H*), 4.12 (q, *J* = 7.2 Hz, 2H, CO$_2$C*H*$_2$CH$_3$), 3.87 (dd, *J* = 9.7, 7.4 Hz, 1H, NCH*H*CH), 3.70 (d, *J* = 11.5 Hz, 1H, CH*H*C, major), 3.46 (d, *J* = 11.5 Hz, 1H, CH*H*C), 2.82 – 2.73 (m, 1H, CH$_2$C*H*CH$_2$), 2.70 – 2.62 (m, 1H, NCH*H*CH), 2.41 (s, 3H, CC*H*$_3$), 2.21 (d, *J* = 3.0 Hz, 1H, CHC*H*C=O), 2.21 – 2.06 (m, 1H, CH*H*C=O), 2.03 (d, *J* = 3.1 Hz, 1H, C*H*CO$_2$), 2.02 – 1.91 (m, 1H, CH*H*C=O), 1.23 (t, *J* = 7.2 Hz, 3H, CH$_2$C*H*$_3$). ^{13}C NMR (101 MHz, $CDCl_3$, from diastereomeric mixture) δ 208.3 (CH$_2$*C*=*O*), 168.3 (*C*O$_2$CH$_2$), 143.9 (*C*CH$_3$), 132.8 (*C*SO$_2$), 129.8 (CH$_3$*C*CH), 127.4 (*C*HCSO$_2$), 61.6 (CO$_2$*C*H$_2$CH$_3$), 53.6 (N*C*H$_2$CH), 48.3 (*C*H$_2$*C*), 44.2 (CH$_2$*C*), 39.6 (*C*HCO$_2$), 39.0 (CH$_2$*C*HCH$_2$), 37.0 (*C*H$_2$C=O), 28.8 (CH*C*HC=O), 21.4 (*C*CH$_3$), 14.0 (CH$_2$*C*H$_3$). **6e-*endo*:** ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.1 Hz, 2H, C*H*CSO$_2$), 7.31 (d, *J* = 8.1 Hz, 2H, CH$_3$CC*H*), 4.10 – 4.03 (m, 2H, CO$_2$C*H*$_2$CH$_3$), 3.75 (dd, *J* = 10.0, 8.3 Hz, 1H, NCH*H*CH), 3.58 (d, *J* = 10.7 Hz, 1H, CH*H*C), 3.17 (d, *J* = 10.7 Hz, 1H, CH*H*C), 2.91 (dd, *J* = 10.0, 7.8 Hz, 1H, NCH*H*CH), 2.82 – 2.73 (m, 1H, CH$_2$C*H*CH$_2$), 2.70 – 2.62 (m, 1H, CH*H*C=O), 2.41 (s, 3H, CC*H*$_3$), 2.22 (d, *J* = 12.4 Hz, 1H, CHC*H*C=O), 2.17 (d, *J* = 12.4 Hz, 1H, C*H*CO$_2$), 2.02 – 1.91 (m, 1H, CH*H*C=O), 1.20 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$). ^{13}C NMR (101 MHz, $CDCl_3$, from diastereomeric mixture) δ 209.7 (CH$_2$*C*=*O*), 168.7 (*C*O$_2$CH$_2$), 144.1 (*C*CH$_3$), 132.2 (*C*SO$_2$), 129.8 (CH$_3$*C*CH), 127.6 (*C*HCSO$_2$), 61.5 (CO$_2$*C*H$_2$CH$_3$), 55.2 (N*C*H$_2$CH), 51.1 (*C*H$_2$C), 46.4 (CH$_2$*C*), 44.7 (*C*H$_2$C=O), 39.8 (*C*HCO$_2$), 36.6 (CH$_2$*C*HCH$_2$), 30.7 (CH*C*HC=O), 21.4 (*C*CH$_3$), 14.0 (CH$_2$*C*H$_3$).

tert*-Butyl 5-oxo-2-tosyloctahydrocyclopropa[1,5]cyclopenta[1,2-c]pyrrole-6-carboxylate, 6f:** From 250 mg of **5c**[12] (0.90 mmol) and 282 mg of salt **1c** (0.99 mmol), a crude mixture of isomeric cyclopropanes was obtained (2:1). After chromatography (Hexane/AcOEt, 3:2), 162 mg (48% yield) of a colorless oil (Rf: 0.30; Hexane/AcOEt, 3:2), was isolated containing a 2:1 mixture of two diasteromers. Major isomer was assigned as **6f-*exo (3aS*, 5aS*,6S*,6aR*) based on: Coupling constant of J_{trans} = 2.3 Hz between H5a and H6 and on the analogy with compound **6b-*exo*.** Minor isomer was assigned as **6f-*endo*** (3aS*, 5aS*,6R*,6aR*) based on: Coupling constant of J_{cis} = 9.4 Hz between H5a and H6 and on the analogy with compound **6b-*endo***. **6f-*exo*:** IR: 2954, 2932, 2867, 1721 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.1 Hz, 2H, C*H*CSO$_2$), 7.36 (d, *J* = 8.0 Hz, 2H, CH$_3$CC*H*), 3.92 (dd, *J* = 9.7, 7.4 Hz, 1H, CH*H*CH), 3.78 (d, *J* = 11.6 Hz, 1H, NCH*H*C), 3.45 (d, *J* = 11.5 Hz, 1H, NCH*H*C), 2.87 – 2.80 (m, 1H, CH$_2$C*H*CH$_2$), 2.62 (t, *J* = 10.0 Hz, 1H, NCH*H*CH), 2.46 (s, 3H, CC*H*$_3$), 2.17 (d, *J* = 2.3 Hz, 1H CHC*H*C=O), 2.21 – 2.15 (m, 1H, CH*H*C=O), 2.02 (d, *J* = 2.3 Hz, 1H, C*H*CO$_2$), 1.99 (d, *J* = 19.4 Hz, 1H, CH*H*C=O), 1.45 (s, 9H, C*(CH$_3$)$_3$*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 208.8 (CH$_2$*C*=*O*), 167.4 (*C*O$_2$CH$_2$), 144.1 (*C*CH$_3$), 132.7 (*C*SO$_2$), 129.9 (*C*HCCH$_3$), 127.6 (*C*HCSO$_2$), 82.8 (*C*(CH$_3$)$_3$), 53.7 (N*C*H$_2$CH), 48.4 (*C*H$_2$C), 44.2 (CH$_2$*C*), 39.7 (*C*HCO$_2$), 39.1 (CH$_2$*C*HCH$_2$), 37.1 (*C*H$_2$C=O), 30.2 (CH*C*HC=O), 28.0 (C*(CH$_3$)$_3$*), 21.6 (*C*CH$_3$). **6f-*endo*:** IR: 2953, 2932, 2865, 1725 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.1 Hz, 2H, C*H*CSO$_2$), 7.36 (d, *J* = 8.0 Hz, 2H, CH$_3$CC*H*), 3.82 (dd, *J* = 9.5, 7.8 Hz, 1H, CH*H*CH), 3.65 (d, *J* = 10.6 Hz, 1H, NCH*H*C), 3.15 (d, *J* = 10.6 Hz, 1H, NCH*H*C), 2.91 (dd, *J* = 9.5, 8.0 Hz, 1H, NCH*H*CH), 2.87 – 2.80 (m, 1H, CH$_2$C*H*CH$_2$), 2.68 (dd, *J* = 18.9, 7.7 Hz, 1H, CH*H*C=O), 2.46 (s, 3H, CC*H*$_3$), 2.36 (d, *J* = 9.4 Hz, 1H, CHC*H*C=O), 2.11 – 2.04 (m, 1H, CH*H*C=O), 2.06 (d, *J* = 9.4 Hz, 1H, C*H*CO$_2$), 1.42 (s, 9H, C*(CH$_3$)$_3$*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 210.0 (CH$_2$*C*=*O*), 167.8 (*C*O$_2$CH$_2$), 144.2 (*C*CH$_3$), 132.3 (*C*SO$_2$), 129.9 (CH$_3$*C*CH), 127.8 (*C*HCSO$_2$), 82.7 (*C*(CH$_3$)$_3$), 55.4 (N*C*H$_2$CH), 51.3 (*C*H$_2$C), 46.3 (CH$_2$*C*), 44.7 (*C*H$_2$C=O), 39.8 (*C*HCO$_2$), 36.7 (CH$_2$*C*HCH$_2$), 32.1 (CH*C*HC=O), 28.0 (C*(CH$_3$)$_3$*), 21.6 (*C*CH$_3$).

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[10] The *ee* was measured by HPLC (Chiralpack AD-H, 4.6mm x 250mm). Optical rotation of the scalemic mixture was positive so the major enantiomer is assigned to (1*S*,5*R*,6*S*) following ref 5.

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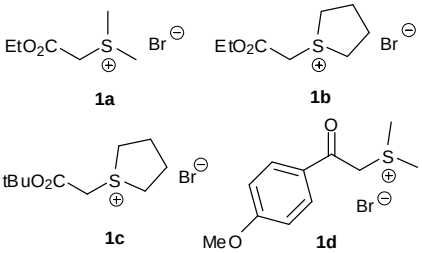

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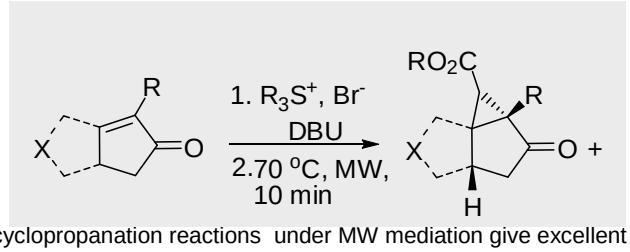

Ylide cyclopropanation reactions under MW mediation give excellent yields and selectivities after short reaction periods. Sterically hindered cyclopentenones and highly connected cyclopropa[c]pentalenes were synthesized in good yields, including a precursor of natural product pentalenene.

*one or two words that highlight the emphasis of the paper or the field of the study

MW assisted ylide cyclopropanation*

Alberto López-Rodríguez, Gema Domínguez, Javier Pérez-Castells*

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Microwave-Mediated Sulfonium Ylide Cyclopropanation. Stereoselective Synthesis of Cyclopropa[c]pentalenes