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An Unexpected Tandem Reaction between *N*-Butadienyl-*N*-alkylketene *N,O*-Trimethylsilylacetals of Propionamide and Activated Dienophiles like *N*-Phenylmaleimide or Acryloyl Chloride

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Abstract. Starting from the *N*-butadienyl-*N*-alkylpropionamides **1a**–**1c** the corresponding *N,O*-trimethylsilylacetals could be obtained using the mixture of LDA and trimethylsilyl chloride in THF. The unexpected reaction sequence *Diels-Alder* reaction/acylation between the *N*-butadienyl-*N*-alkylketene *N,O*-trimethylsilylacetal of propionamide (**2a**–**2b**) and *N*-phenylmaleimide produced tricyclic products *rac*-**5a** –*rac*-**5b** and bicyclic products *rac*-**6a** – *rac*-**6b** with high diastereoselectivity. The reaction of the *N,O*-trimethylsilylacetals **2a** and **2c** with acryloyl chloride in a similar sequence gave the bicyclic products *rac*-**8a** and *rac*-**8c**. The stepwise synthesis of bicyclic systems of this general structure could only be successfully executed in 26% yield treating the *Diels-Alder* product *rac*-**10** with LDA.

Introduction

Nature has used sequential transformations in the biosynthetic processes leading to alkaloids, terpenoids, and steroids [1]. The beauty and the efficiency of these multistep reactions has motivated chemists to imitate these processes [2–5] since the time the biomimetic synthesis of tropinone has been reported by *Robinson* [6–8]. Tandem reactions always belonged to the most important processes in organic synthesis. Many of the so-called name reactions are more or less complex sequences of tandem reactions [9]. Especially in the synthesis of heterocycles tandem reactions are widely used [10–12]. For a long time, most tandem reactions were found by serendipity.

In recent years, more and more planned tandem reactions have been reported [13–15]. There are obvious advantages carrying out two or more steps in one pot: losses due to the workup can be reduced, the synthesis becomes more convergent, and finally it is possible to use sensitive intermediates, without isolating them.

Combining two synthetically important reactions should lead to processes with considerably enhanced synthetic potential. These arguments lead us to study the combination of the *Diels-Alder* reaction with the [3,3]-sigmatropic rearrangement [16] (*Scheme 1*). The use of dienes substituted at C(1) with groups which can rearrange after the cycloaddition leads to 1,4-disubstituted cyclohex-2-enes. The tandem reaction allows the synthesis of the product by an alternative synthetic plan, than the one which is the result of a straightforward retrosynthetic analysis. The relative configuration at C(1) and C(4) of the cyclohexene ring system can be predicted by the rules governing the two reactions which are combined in the tandem process and the double bond situated between the two functional groups can be modified in a regio- and stereoselective way. In the case of the (*E*)-buta-1,3-dienyl-thiocyanate it has been shown, that a tandem reaction made up of a *Diels-Alder* reaction and of a [3,3]-sigmatropic shift can be successfully accomplished. Using moderately acctivated dienophiles it was possible to selectively trap the product of the tandem reaction by the addition of EtOH to the formed isothiocyanate. Only the selective trapping allowed to obtain good yields of the desired products. Using the (*E*)-buta-1,3-dienyl-thiocyanate as diene a tandem reaction made up of three seperate steps, *Diels-Alder* reaction, a [3,3]-sigmatropic shift, and finally the trapping of the isocyanate with EtOH has been developped.

Results and Discussion

In order to increase the synthetic utility of the combination of a *Diels-Alder* reaction with a rearrangement process we were looking for rearrangements whereby during the process C–C bonds are formed from a carbon-heteroatom bond. The aza-[3,3]-sigmatropic shift of *N*-allyl-*N,O*-ketene acetals has been studied in the groups of *Ireland* and *Kurth* [17][18]. The C–C bond is formed in a diastereoselective manner, but unfortunately, relatively high temperatures (150–180°) are necessary to induce the rearrangement process. No tri-

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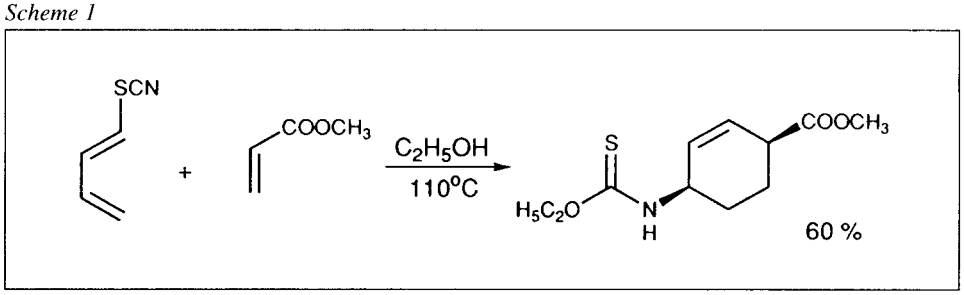
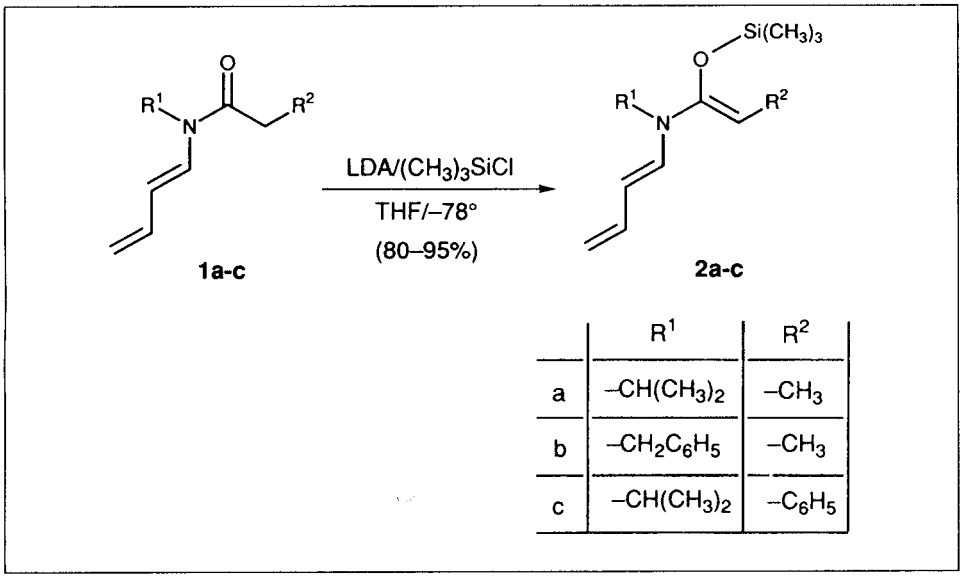
Scheme 1



als to rearrange the *O*-silyl derivative of an *N,O*-ketene acetal has been reported. Despite these facts we decided to study the behavior of the *N*-butadienyl-*N*-isopropylketene *N,O*-trimethylsilylacetal of propionamide **2a**. The obvious starting material was the corresponding propionamide **1a**, a moderately activated diene, which undergoes [4+2]-cycloaddition with a series of activated dienophiles [19][20]. The ketene *N,O*-acetal **2a** was hoped to undergo the *Diels-Alder* reaction followed by a [3,3]-sigmatropic rearrangement. This process should lead to cyclohexene derivatives substituted at C(1) and C(4) with control of the relative configuration.

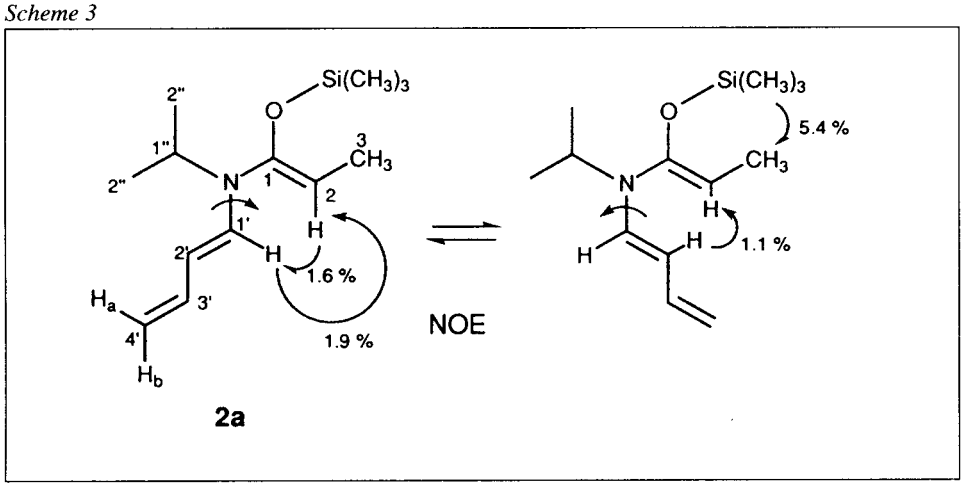
The synthesis of the ketene *N,O*-acetal **2a** starting from the propionamide **1a** was straightforward. Deprotonation of the amide in the presence of trimethylsilylchloride [21] gave a 95% yield of isolated **2a** as a liquid, which was extremely sensitive against hydrolysis (*Scheme 2*). Only the (*Z*)-diastereoisomer was obtained. This was independently proven by NOE experiments (*Scheme 3*): enhancements of the olefinic proton of **2a** was observed, when the α- and β-protons of the butadienyl portion were irradiated. At the same time, these results reveal the presence of two rotamers around the C–N bond. The $A^{1,3}$-strain [22] between the substituent(s) on the nitrogen of the amide and the substituent on the α-methylene group, in our case the Me group, has been cited to explain the (*Z*)-stereoselectivity during the deprotonation of *N,N*-dialkylamides [23]. If this argument is valid, the s-*cis*-conformation should be prefered for the starting material. NOE Experiments using the dienamide **1a** clearly indicate that already the starting material shows a conformational preference for the s-*cis*-conformation (*Scheme 4*). Also the dienamide **1a** is present in two conformations around the C–N bond. The *N*-benzyl derivative **1b** and the *N*-isopropyl derivative of the phenylacetic acid dienamid **1c** could be transformed under the same reaction conditions into the corresponding ketene *N,O*-trimethylsilylacetals **2b** and **2c**.

Scheme 2

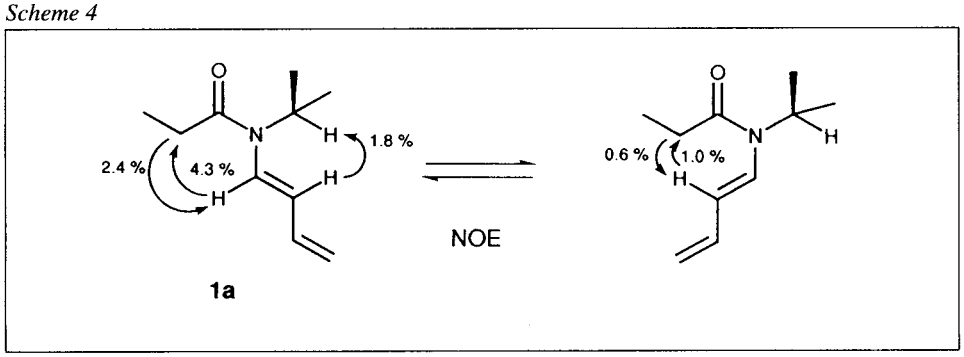


	R^1	R^2
a	$-CH(CH_3)_2$	$-CH_3$
b	$-CH_2C_6H_5$	$-CH_3$
c	$-CH(CH_3)_2$	$-C_6H_5$

Scheme 3



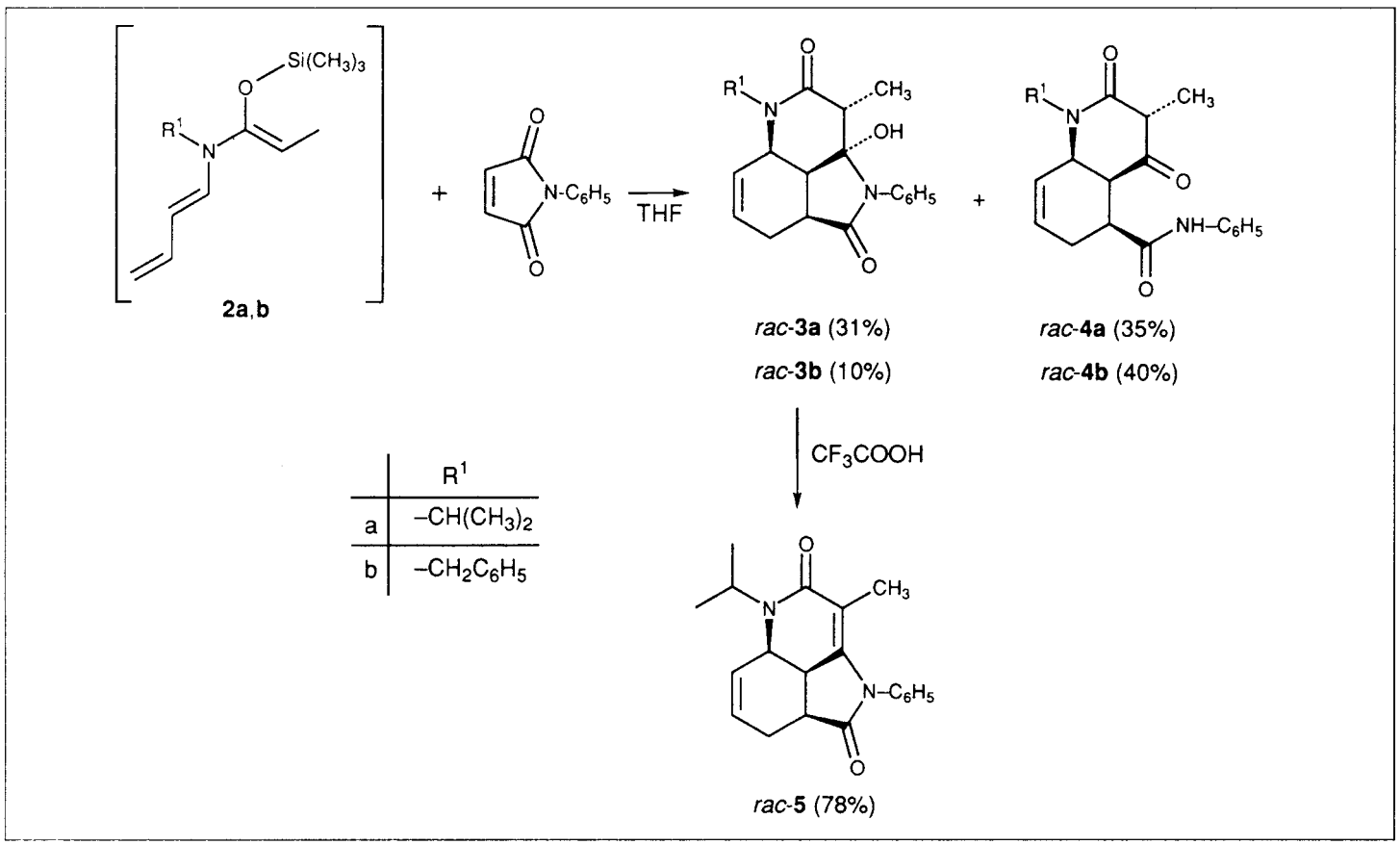
Scheme 4



The reaction of the ketene *N,O*-acetals **2a** and **2b**, respectively, with *N*-phenylmaleimide in THF at room temperature leads to product formation already at –78° (*Scheme 5*). Addition of MeOH to the reaction mixture and evaporation of the solvent yielded a raw material which was composed of two products **3a** and **4a**, respectively, and **3b** and **4b**, respectively, according to the TLC analysis. The two products **3a** and **4a** could be separated by fractional crystallisation from $CHCl_3/Et_2O$ *ca.* 1:1 in 66% overall yield. From the ^{1}H-NMR spectra of both products, it was immediately clear that a cycloaddition between the two substances had taken place.

Careful analysis of the 360-MHz ^{1}H-NMR spectrum and decoupling experiments proved that it was not the expected tandem reaction *Diels-Alder* reaction/[3,3]-sigmatropic shift which had taken place but an unexpected combination of a *Diels-Alder* reaction with an acylation step. The tricyclic product *rac*-**3a** as well as the bicyclic *rac*-**4a** were present each as one single diastereoisomer. The relative configuration at the ring junction for both products was all *cis* as one would expect from an *endo*-selective *Diels-Alder* reaction. A series of NOE experiments allowed to establish the relative positions of the H-atoms at the ring junction. More astonishing was the fact that the configuration at C(3) was also unique. The H-atom at this position could be exchanged against deuterium without epimerization. Therefore, the observed relative configurations must be the thermodynamically more stable ones. The relative configuration was established by the following NOE experiments (*Scheme 6*): In the case of the tricyclic compound *rac*-**3a** a NOE enhancement of 7.3% could be observed

Scheme 5

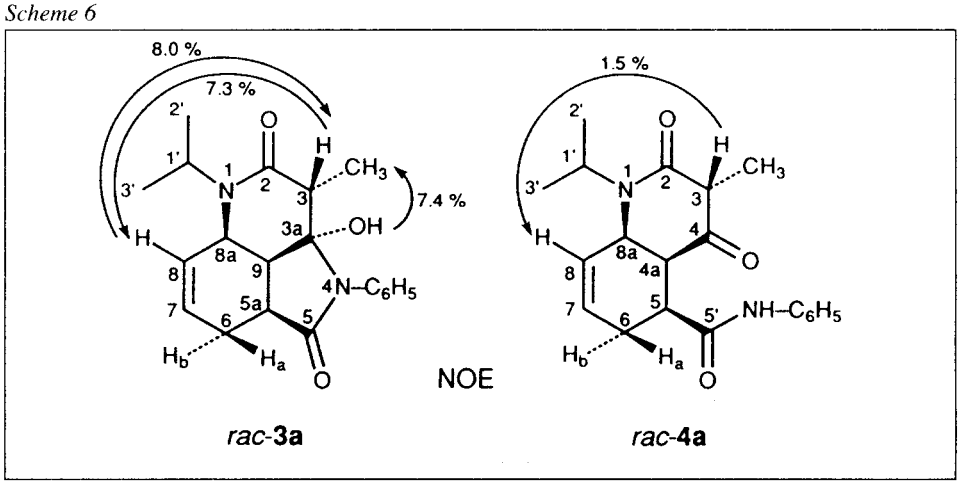


irradiating H–C(3) and observing H–C(8). This assignment is also in good agreement with shift arguments. The Me group at C(3) resonates at extraordinary high field (0.59 ppm) which can be explained by the influence of the ring current of the nearby Ph group. The relative configuration of the bicyclic product *rac*-**4a** was assigned in an analogous way (*Scheme 6*). Using the *N*-benzyl derivative **2b** as starting material similar results were obtained. A 10% yield of the tricyclic product *rac*-**3b** and a 40% yield the bicyclic product *rac*-**4b** were obtained (*Scheme 5*).

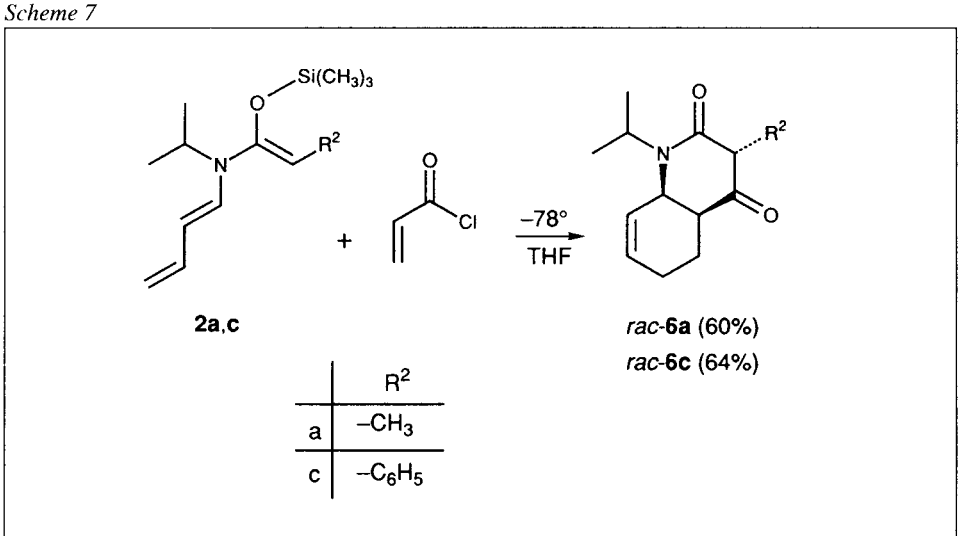
The tricyclic product *rac*-**3a** could be dehydrated treating it with CF_3COOH in CH_3OH. The vinylogous urea *rac*-**5** was obtained in 78% yield. The spectral data are in good accordance with the proposed structure. The only surprising fact is the occurrence of a ^5J-coupling between CH_3–C(3) and H–C(9) of 1.8 Hz.

The ketene *N,O*-trimethylsilylacetals **2a** and **2c** could be brought to react with 2 equiv. of acryloyl chloride as dienophile. The bicyclic products *rac*-**6a** and *rac*-**6c**, respectively, could be isolated diastereomerically pure in 60 and 64% yield, respectively. The relative configuration at the ring junction as well as the relative configuration of CH_3–C(3) was inequivocally determined with the help of NOE experiments. Deuterium-exchange experiments showed that H–C(3) could be replaced by deuterium without changing the

Scheme 6



Scheme 7

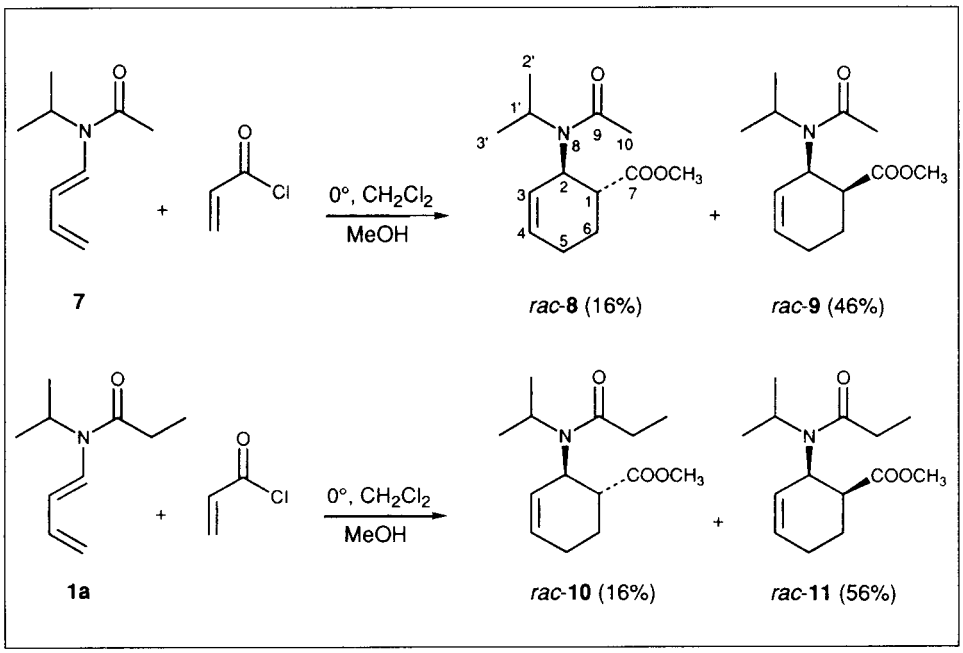


relative configuration at that center. The isolated diastereoisomer represents, therefore, the thermodynamically more stable relative configuration at C(3). The bulky i-Pr group on the lactam nitrogen probabely fixes the lactam into a pseudo equatorial postition relative to the cyclohexene ring. The lactam ring itself adopts a boat conformation, minimizing thereby the interactions between the i-Pr substituent and the adjecent ring C-atom. This conformational lock of the lactam ring puts H–C(3) in an axial and by consequence the methyl group in an equatorial position. There is an ideal overlap between the C–H bond and the π-bonds of the two adjecent carbonyl groups.

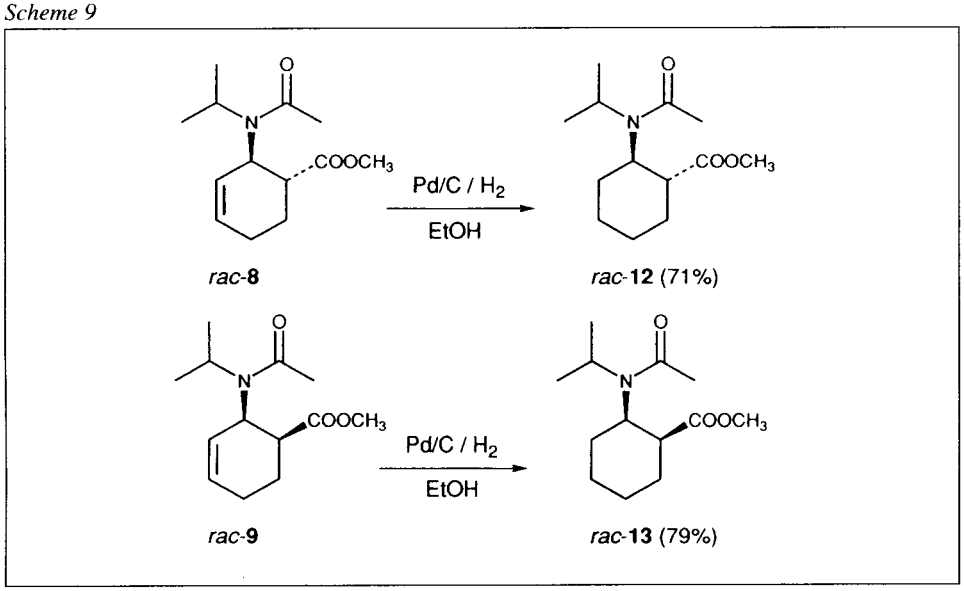
Using crotonyl chloride and methacryl chloride as dienophile only minute amounts of cycloadducts could be detected in the ^{1}H-NMR spectrum of the raw material. Diisopropylamine is present in the reaction mixture, which stems from the synthesis of the ketene *N,O*-trimethylsilylacetal. Reaction of the diisopropylamine with the acid chloride produces HCl, which immediately destroys the ketene acetal. In order to avoid the formation of HCl two sort of experiments were carried out. To remove the proton of the diisopropylamine after the formation of the ketene *N,O*-trimethylsilylacetal **2a**, a second equiv. of BuLi was added. This solution was treated with crotonyl chloride, methacryl chloride, and acryloyl chloride, respectively. In the first two cases almost no cycloadduct could be detected and even in the third case the product formation was highly reduced. Adding to the mixture containing **2a**, LDA and acryloyl chloride 2 equiv. of LiCl allowed the reaction to proceed at a normal rate and a 56% yield of *rac*-**6a** could be isolated, comparable to the 60% yield obtained without the BuLi treatment. In the second sort of experiment **2a** was isolated and the LiCl was precipitated by the addition of hexane. The soln. of **2a** free of LiCl in $CHCl_3$ did not react with added *N*-phenylmaleimide as dienophile. The acylation of imides by ketene *N,O*-trimethylsilylacetal without the addition of *Lewis* acids is without precedent. The ease of this new tandem reaction composed of a *Diels-Alder* reaction and an acylation could be the consequence of the steric compression of the two reacting functional groups in the cycloadduct and of the action of LiCl as *Lewis* acid as the experiments reported above seem to indicate.

Finally, we decided to investigate if the product of the tandem reaction could not be obtained with similar ease using a stepwise procedure. The *Diels-Alder* reaction of the dienamides **1a** and **7** with acryloyl chloride in CH_2Cl_2 at 0° overnight and treating the reaction mixture with CH_3OH allowed to isolate the mixture of the *trans*- and the *cis*-disubstituted cyclohexene rings *rac*-**10** and *rac*-**11** in 16 and 56% yield, respectively, and the acetamide derivatives of the cycloadduct *rac*-**8** and *rac*-**9** in 16 and 46% yield, respectively (*Scheme 8*). Attribution of the relative configuration by NMR methods proved to be difficult. The preference for one diastereoisomer under these relatively mild reaction conditions prompted us to assume that the major product of the cycloaddition is the *cis*-substituted product

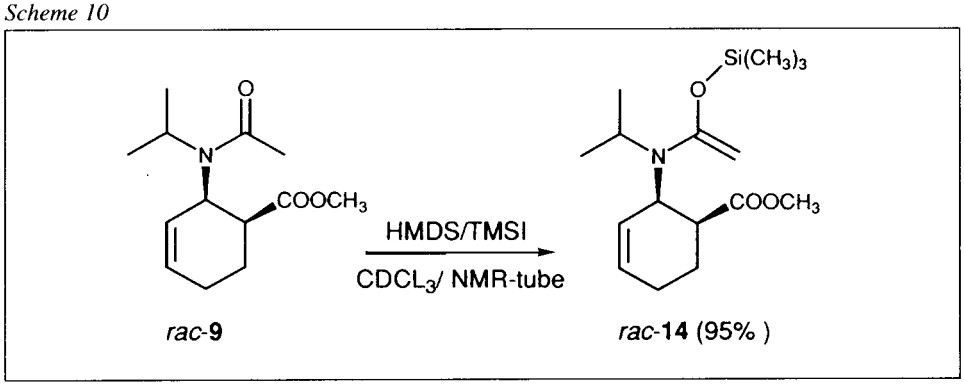
Scheme 8



Scheme 9



Scheme 10

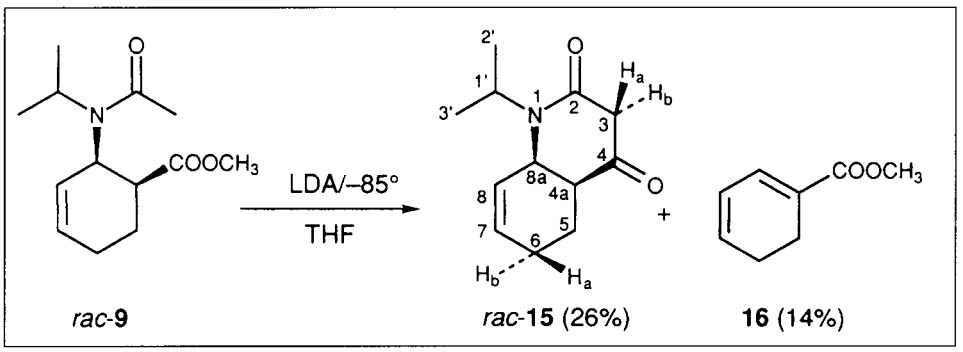


which is formed *via* an *endo*-transition state. To substantiate the tentative assignment the two diastereoisomeric cycloadducts, *rac*-**8** and *rac*-**9** were reduced with Pd/C as catalyst to obtain the disubstituted cyclohexane derivatives *rac*-**12** and *rac*-**13** (*Scheme 9*). The ^{1}H-NMR data were much easier to interpret and allowed an uneqivocal identification of the two diastereoisomers.

To check if the tandem reaction could be accomplished in a stepwise manner, *rac*-**9** was transformed into the ketene *N,O*-trimethylsilylacetal *rac*-**14** treating the amide with trimethylsilyl iodide and hexamethyldisilazane in $CHCl_3$ (*Scheme 10*). The ketene *N,O*-acetal *rac*-**14** was formed, but did not react any further. Treating the cyclohexene *rac*-**9** with LDA at –85° in THF to form the lithium enolate instead allowed to isolate the bicyclic compound *rac*-**15** in a moderate 26% yield (*Scheme 11*). The major side reaction was the base-catalyzed elimination of the deprotonated *N*-isopropyl acetamide to form methyl cyclohexa-1,3-dienyl-1-carboxylate (**16**) in 14% yield. The structure of *rac*-**15** could be secured by an X-ray analysis (*Fig.*). The structure clearly shows that the cyclohexene ring of *rac*-**15** is in a half chair conformation, whereas the annulated lactam ring is in a boat conformation. This corresponds to the conformation which was predicted from the analysis of the NOE experiments in solution. This conformation of the bicyclic systems allows to remove the bulcky *N*-isopropyl substituent as far from the ring system as possible. The (pro-*S*)-H–C(3) is fixed in an axial position projecting towards the inside of the roof like molecule. The almost perfect alignment of this hydrogen with the π-orbitals of the two adjecent C=O bonds (dihedral angles: between O_1 and the (pro-*S*)-H–C(3): 102.2°; between O_2 and the (pro-*S*)-H–C(3): –87.2°) explains why the (pro-*S*)-H, which is sterically more hindered, undergoes the base catalysed deuterium exchange faster than the (pro-*R*)-H. At the same time the relatively short distance between the (pro-*S*)-H and H–C(8) (distance: 3.00 Å) and H–C(7) (distance: 3.76 Å) is a necessary condition for the observation of a NOE effect. At the same time the difference of the two distances explains why only the NOE enhancement with H–C(8) is observed. The X-ray analysis nicely complements the structural information deduced from the studies in solution and shows, that the conformation of these bicyclic systems must be very similar in the crystal and in solution.

In summary the ketene *N,O*-acetals **2a–2c** undergo a tandem reaction *Diels-Alder* reaction/acylation reaction with unprecedented ease. The sequence *Diels-Alder* reaction first and acylation second is at the moment the preferred mechanistic hypothesis for this tandem process. This sequence explains without difficulties the observed relative configurations at the chiral centres formed. The second argument in favor of this sequence stems from the fact, that acylation between a ketene *N,O*-acetal and an imide without addition of a *Lewis* acid seems to be without precedent. The only *Lewis* acid present during this reaction is LiCl. As could be shown the presence of LiCl is necessary to obtain the products of the tandem reaction in good yield. The exact function of the LiCl could not be pinned down. The LiCl could catalyse the *Diels-Alder* reaction as well as the acylation process. Finally, the tandem process can in one case also be executed in a stepwise manner. The overall yield of the stepwise procedure is not very satisfactory which demonstrates one of the principal advantages of a tandem process.

Scheme 11



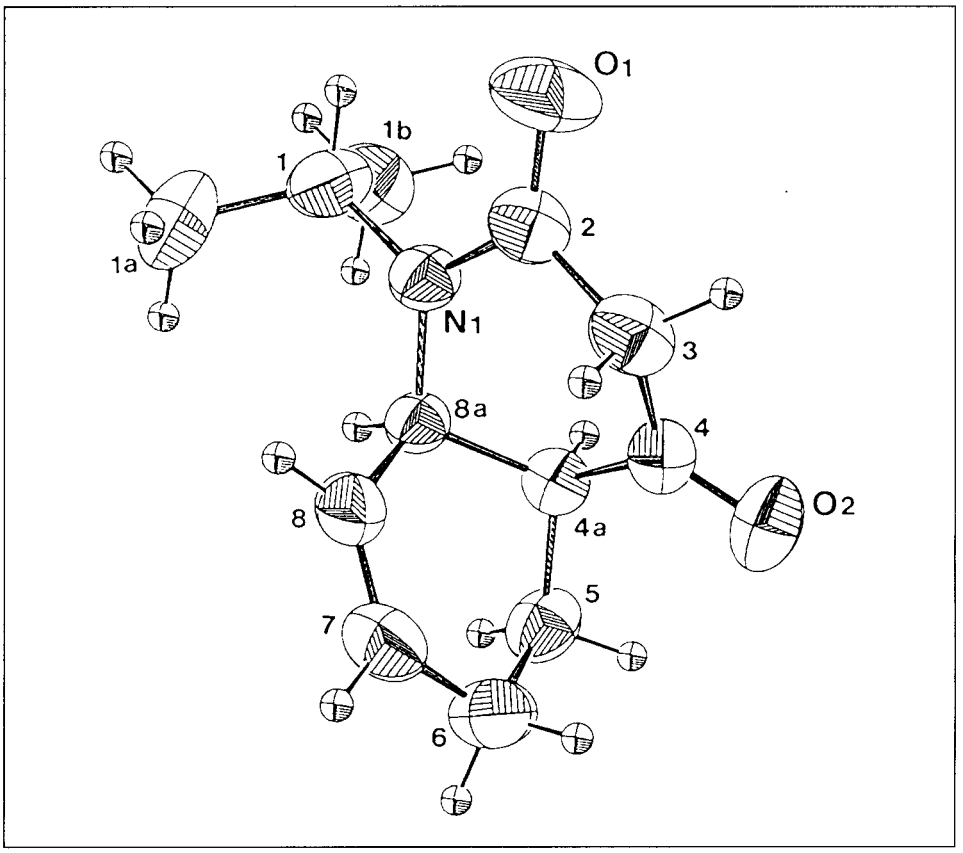


Figure. *ORTEP-II* [28] *plot of rac*-**15**. Arbitary labelling scheme and ellipsoids at 50% probability.

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Experimental

General. All reactions were carried out under N_2. Solvents were dried by distillation from drying agents as follows: THF (Na), Et_2O (CaH_2), CH_2Cl_2 (CaH_2), MeOH (Mg), EtOH (Mg). Silica gel *60* (*Merck*) was used for flash chromatography (FC). M.p. were determined in open capillary

tubes on a *Kofler* melting point apparatus (*Thermovar, C. Reichert AG*, Vienna) and are uncorrected. IR Spectra: *Perkin Elmer 599* and *Perkin Elmer 1720X* FT-IR spectrophotometer in $CHCl_3$ unless otherwise noted. NMR Spectra: ^1H at 360 MHz on a *Bruker AM 360* or at 400 MHz on a *Bruker AMX 400*. ^{13}C at 90 MHz on a *Bruker Am 360* or at 100 MHz on a *Bruker AMX 400*. Routine NMR spectra were measured on a *Varian Gemini 200*. If not otherwise mentioned spectra were measured in $CDCl_3$ with $CHCl_3$ as internal standard (d = 7.27); chemical shifts (δ) in ppm; coupling constants J in Hz. MS: *Vacuum Generator Micromass 7070E* instrument or a *NERMAG R30-10* (70 eV); relative peak intensities are given in % of the base peak (= 100%). Microanalyses were performed in the microanal. laboratories of *Ciba-Geigy Ltd.*, Marly/Fribourg.

(Z)-N-[(E)-Buta-1,3-dienyl]-N-isopropyl-1-[(trimethylsilyl)oxy]prop-1-enamine (**2a**). In a flamedried three-necked flask fitted with magnetic stirrer, septum, N_2 bubbler, and thermometer, a 1.6M soln. of BuLi (hexane, 8.8 ml, 14 mmol) was added dropwise to a soln. of anh. $(i\text{-}Pr)_2NH$ (2.4 ml, 17.2 mmol) in THF (32 ml) at –78° and the mixture was stirred for 30 min at 0°. The mixture was cooled to –78° and freshly distilled TMSCl (1.8 ml, 14 mmol) and a soln. of **1a** (2.2 g, 13.2 mmol) in THF (10 ml) were added slowly at the same temp. After addition was complete, stirring was continued for 1 h at –78° and the mixture was then warmed slowly to r.t. To get a NMR spectrum of **2a**, 1 ml of the yellow soln. was taken, the volatile components were evaporated and the residue dissolved in $CDCl_3$, which was filtered twice over basic Al_2O_3. The soln. was filtered directly in a dried NMR tube. Yield: 95%, by GC. ^1H-NMR (360 MHz, $CDCl_3$): 6.18 (*dt*, J = 16.7, 10.6, 10.3, H–C(3')); 6.15 (*d*, J = 13.8, H–C(1')); 5.26 (*dd*, J = 13.8, 10.6, H–C(2')); 4.71 (*dd*, J = 16.7, 2.1, H_a–C(4')); 4.49 (*dd*, J = 10.3, 2.1, H_b–C(4')); 4.28 (*q*, J = 6.6, H–C(2)); 3.58 (*sept.*, J = 6.8, H–C(1'')); 1.51 (*d*, J = 6.6, CH_3(3)); 1.13 (*d*, J = 6.8, 2 x CH_3(2'')); 0.12 (*s*, $(CH_3)_3Si$). ^{13}C-NMR (90 MHz, $CDCl_3$): 147.5 (*s*, C(1)); 137.3, 137.1 (2*d*, C(1'), C(3')); 106.0 (*t*, C(4')), 103.4 (*d*, C(2')), 98.1 (*d*, C(2)); 49.3 (*d*, C(1'')), 20.2 (*q*, C(2'')); 11.0 (*q*, C(3)); 0.5 (*q*, $(CH_3)_3Si$). GC-MS: 239 (19, M^+), 224 (20, $[M-CH_3]^+$), 116 (17), 106 (11), 73 (100, $[(CH_3)_3Si]^+$), 53 (11).

(Z)-N-Benzyl-N-[(E)-buta-1,3-dienyl]-1-[(trimethylsilyl)oxy]prop-1-enamine (**2b**). Analogously to the transformation of **1a** to **2a**, **2b** (oil, 80%, by ^1H-NMR) was prepared from **1b** (2.84 g, 13.93 mmol). ^1H-NMR (360 MHz, $CDCl_3$): 7.30–7.10 (*m*, , arom. H); 6.69 (*d*, J = 13.7, H–C(1')); 6.24 (*dt*, J = 17.0, 10.3, H–C(3')); 5.18 (*dd*, J = 13.7, 10.3, H–C(2')); 4.72 (*dd*, J = 17.0, 1.6, H_a–C(4')); 4.57 (*dd*, J = 10.3, 1.6, H_b–C(4')); 4.48 (*s*, CH_2(1'')); 4.12 (*q*, J = 6.7, H–C(2)); 1.54 (*d*, J = 6.7, H–C(3)); 0.21 (*s*, $(CH_3)_3Si$).

(Z)-N-[(E)-Buta-1,3-dienyl]-N-isopropyl-1-[(trimethylsilyl)oxy]ethenamine (**2c**). With the same procedure, **2c** (oil, 85%, by ^1H-NMR) was prepared from **1c** (3.02 g, 13.2 mmol). ^1H-NMR (360 MHz, $CDCl_3$): 7.48–7.10 (*m*, 5 arom. H); 6.29 (*dt*, J = 17.9, 10.3, H–C(3')); 6.28 (*d*, J = 13.5, H–C(1')); 5.50 (dd, J = 13.7, 10.4, H–C(2')); 5.27 (*s*, H–C(2)); 4.85 (dd, J = 17.2, 1.7, H_a–C(4')); 4.58 (*dd*, J = 10.2, 1.7, H_b–C(4')); 3.79 (*sept.*, J = 6.8, H–C(1'')); 1.28 (*d*, J = 6.8, 2 x CH_3(2'')); 0.20 (*s*, $(CH_3)_3Si$).

(3RS,3aRS,5aSR,8aRS,9SR)-1,2,3,3a,4,5,5a,6,8a,9-Decahydro-3a-hydroxy-1-isopropyl-3-methyl-4-phenylpyrrolo[2,3,4-de]chinoline-2,5-dion (*rac*-**3a**) *and (3RS,4aSR,5SR,8aRS)-1,2,3,4,4a,5,6,8a-Octahydro-5-(N-phenylcarboxamido)-1-isopropyl-3-methylchinoline-2,4-dion* (*rac*-**4a**). To the soln. of **2a** prepared from **1a** (2.2 g, 13.2 mmol) (see above) was added dropwise a soln. of *N*-phenylmaleimide (2.28 g, 13.2 mmol) in THF (5 ml) at r.t. The color of the reaction mixture changed during the addition from yellow to brown, with the formation of a light brown precipitate. The mixture was stirred at amb. temp. during 12 h and the then violet soln. was hydrolyzed with MeOH (5 ml) . After evaporation of the solvent on the rotavap the darkviolet residue was dissolved in CHCl3 (30 ml) and washed with H_2O (3 x 10 ml). The org. phase was dried over $MgSO_4$ and filtered over *Celite*/active carbon. Fractional crystallization of the violet soln. with $CHCl_3$/Et_2O at 0° gave *rac*-**3a** (1.4 g, 31%) as white crystals. M.p. 197–198°. IR (KBr): 3320, 3040, 2980, 2960, 2850, 1685, 1650, 1595, 1495, 1455, 1440, 1390, 1275, 1245, 1210, 1105, 1010, 885, 830, 760, 745, 695. ^1H-NMR (360 MHz, $CDCl_3$): 7.43–7.16 (*m*, 5, arom. H) ; 6.08 (*ddt*, J = 9.5, 7.3, 3.1, H–C(7)); 5.78 (*m*, J = 9.5, H–C(8)); 4.94 (*sept.*, J = 6.8, H–C(1')); 4.13 (br. *s*, OH); 3.90 (*m*, H–C(8a)); 3.12 (*m*, H–C(5a)); 2.89 (*m*, H–C(9)); 2.85 (*m*, H_a–C(6)); 2.62 (*q*, J = 6.8, H–C(3)); 2.11 (*m*, H_b–C(6)); 1.16, 1.13 (2*d*, J = 6.8, CH_3(2') and CH_3(3')); 0.59 (*d*, J = 6.8, CH_3–C(3)). ^{13}C-NMR (100 MHz, (D_6)DMSO): 174.8, 168.7 (2*s*, C(2), C(5)); 137.6, 132.7, 128.2, 127.4, 129.0, 128.5 (*s* and 5*d*, arom. or olef.); 92.0 (*s*, C(3a)); 49.0 (*d*, C(1')); 46.1 (*d*, C(8a)); 45.5 (*d*, C(5a)); 43.6 (*d*, C(9)); 38.7 (*d*, C(3)); 23.7 (*t*, C(6)); 19.7, 19.4 (2*q*, C(2'), C(3')); 9.0 (*q*, CH_3–C(3)). MS: 341 (19, $[M+1]^+$), 340 (79, $[M]^+$), 325 (12, $[M-CH_3]^+$), 298 (7), 283 (17), 248 (15), 241 (16), 237 (24), 178 (10), 167 (21), 166 (10), 164 (10), 163 (60), 119 (12), 117 (18), 115 (14), 111 (48) 107 (11), 105 (14), 100 (11), 96 (15), 94 (28), 93 (100), 80 (15), 79 (66), 77 (31). Anal. calc. for $C_{20}H_{24}N_2O_3$ (340.43): C 70.56, H 7.11, N 8.23; found: C 70.41, H 7.08, N 8.22.

Further crystallization at –20° furnished *rac*-**4a** (1.56 g, 35%) as white crystals. M.p. 190°. IR (KBr): 3340, 3040, 1730, 1695, 1635, 1605 1550, 1470, 1445, 1330, 1255, 1210, 1070, 760, 700. ^1H-NMR (360 MHz, $CDCl_3$): 9.01 (br. *s*, H–N); 7.58–7.12 (*m*, J = 8.4, 7.5, 1.1, 5 arom.H); 5.93 (*ddt*, J = 10.1, 4.9, 2.3, 2.3, H–C(7)); 5.67 (*ddd*, J = 10.1, 2.6, 1.5, H–C(8)); 4.97 (*sept.*, J = 6.9, H–C(1')); 4.36 (*m*, H–C(8a)); 3.50 (*q*, J = 6.9 H–C(3)); 3.22 (*m*, H–C(4a)); 3.02 (*ddd*, J = 11.8, 5.2, 2.8, H–C(5)); 2.49 (*m*, J = 17.9, H_b–C(6)); 2.33 (*m*, H_a–C(6)); 1.32 (*d*, J = 6.9, CH_3–C(3)); 1.25, 1.17 (2*d*, J = 6.8, CH_3(2'), CH_3(3')). ^{13}C-NMR (90 MHz, $CDCl_3$): 209.1 (*s*, C(4)); 169.9, 166.9 (2*s*, C(2), C(5')); 137.9, 129.8, 128.8l, 124.5, 122.9, 120.5 (*s* and 5*d*, arom. or olef.); 51.8 (*d*, C(1')); 49.8–45.2 (4*d*, C(8a), C(3), C(4a) and C(5)); 25.1 (*t*, C(6)); 20.2, 20.0 (2*q*, C(2'), C(3')); 8.9 (*q*, CH_3–C(3)). MS: 341 (1, $[M+1]^+$), 340 (6, M^+), 163 (22), 120 (10), 117 (11), 94 (11), 93 (100), 92 (14), 91 (21), 83 (12), 79 (50), 78 (10), 77 (50), 70 (12), 65 (16), 55 (10), 43 (25), 42 (12), 41 (22). Anal. calc. for $C_{20}H_{24}N_2O_3$ (340.43): C 70.56, H 7.11, N 8.23; found: C 70.49, H 7.28, N 8.11.

(3RS,3aRS,5aSR,8aRS,9SR)-1,2,3,3a,4,5,5a,6,8a,9-Decahydro-3a-hydroxy-1-benzyl-3-methyl-4-phenylpyrrolo[2,3,4-de]chinoline-2,5-dione (*rac*-**3b**) *and (3RS,4aSR, 5SR,8aRS)-1,2,3,4,4a,5,6,8a-Octahydro-5-(N-phenylcarboxamido)-1-benzyl-3-methylchinoline-2,4-dione* (*rac*-**4b**).

Analogously to the transformation of **2a** to *rac*-**3a** and *rac*-**4a**, *rac*-**3b** and *rac*-**4b** were prepared from **2b** which was prepared from **1a** (2.84 g, 13.2 mmol) (see above). In this way we synthesized *rac*-**3b** (oil, 0.51 g, 10%). IR (KBr): 3600–3200, 3060, 2950, 2930, 2860, 1710, 1650, 1500, 1380, 1215, 1100, 1070, 760, 700. ^1H-NMR (360 MHz, (D_4)MeOH): 7.44–7.18 (*m*, 10 arom. H); 6.06 (*dddd*, J = 9.9, 6.9, 2.9, 2.7, H–C(7)); 5.82 (*dddd*, J = 9.9, 3.0, 2.7, 0.8, H–C(8)); 4.99 (*d*, J = 14.8, H_a–C(1')); 4.51 (*d*, J = 14.8, H_b–C(1')); 4.08 (*dddt*, J = 7.3, 3.0, 2.7, 2.7, H–C(8a)); 3.19 (*ddd*, J = 10.3, 6.3, 2.1, H–C(5a)); 2.97 (*ddd*, J = 10.3, 7.3, 0.8, H–C(9)); 2.76 (*q*, J = 6.8, H–C(3)); 2.66 (*ddd*, J = 15.7, 6.9, 2.1, H_a–C(6)); 2.13 (*ddt*, J = 15.7, 7.3, 2.9, 2.7, H_b–C(6)); 0.69 (*d*, J = 6.8, CH_3–C(3)). ^{13}C-NMR (90 MHz, (D_4)MeOH): 178.3, 173.5 (2*s*, C(5), C(2)); 138.6, 138.4, 131.4, 130.9, 130.5, 130.4, 130.0, 129.7, 129.4, 128.9 (2*s* and 8 *d*, arom. or olef.), 94.7 (*s*, C(3a)); 79.7 (*d*, C(8a)); 53.7 (*d*, C(5a)); 51.3 (*t*, C(1')); 47.5 (*d*, C(9)); 40.1 (*d*, C(3)); 24.9 (*t*, C(6)); 9.9 (*q*, CH_3–C(3)). MS: 388 (5, M^+), 370 (9), 295 (43, $[M-C_6H_5NH_2]^+$), 250 (25), 106 (36, $[NHCH_2C_6H_5]^+$), 93 (75), 91 (100, $[C_7H_7]^+$), 77 (30, $[C_6H_5]^+$).

The product *rac*-**4b**, was fractionally crystallized in 40% yield (oil, 2.05 g). IR (KBr): 3350–3200, 3040, 2920, 2750–2500, 1725, 1670, 1550, 1500, 1470, 1450, 1380, 1360, 1335, 1140, 1080, 1065, 760, 700. ^1H-NMR (360 MHz, $CDCl_3$): The signals of two rotamers were obtained in a ratio of 58:42. *Rotamer A*: 8.65 (*s*, N–H); 7.47–7.01 (*m*, 10 arom. H); 5.86 (*dddt*, J = 10.0, 4.6, 2.9, 2.3, H–C(7)); 5.56 (*dqd*, J = 10.9, 10.9, 10.0, H–C(8)); 5.10 (*d*, J = 14.7, H_a–C(1')); 4.38 (*d*, J = 14.7, H_b–C(1')); 4.21 (*m*, H–C(8a)); 3.40 (*q*, J = 7.1, H–C(3)); 3.24 (*m*, H–C(4a)); 2.79 (*ddd*, J = 11.2, 5.7, 2.8, H–C(5)); 2.37 (*m*, H_b–C(6), H_a–C(6)); 1.40 (*d*, J = 7.1, CH_3–C(3)); *Rotamer B*: 8.12 (*s*, N–H); 7.47–7.01 (*m*, 10 arom. H); 5.80 (*dddt*, J = 10.0, 4.1, 2.9, 2.0, H–C(7)); 5.63 (*m*, H–C(8)); 5.35 (*d*, J = 14.9, H_a–C(1')); 4.18 (*m*, H–C(8a)); 4.14 (*d*, J = 14.9, H_b–C(1')); 3.47 (*m*, H–C(4a)); 3.24 (*q*, H–C(3)); 2.79 (*m*, H–C(5)); 2.69 (*m*, H_a–C(6)); 2.37 (*m*, H_b–C(6)); 1.40 (*d*, CH_3–C(3)). ^{13}C-NMR (90 MHz, $CDCl_3$): 208.4 (*s*, C(4)); 169.7, 167.8 (2*s*, C(5'), C(2)); 138.6, 137.7, 136.2, 129.6, 128.9, 128.3, 128.1, 126.6, 124.5, 120.2 (2 *s* and 8 *d*, arom. or olef.); 54.6 (*d*, C(8a)); 51.4 (*d*, C(4a)); 49.8 (*t*, C(1')); 47.0 (*d*, C(5)); 45.1 (*d*, C(3)); 25.1 (*t*, C(6)); 10.3 (*q*, CH_3–C(3)). MS: 388 (12, M^+), 370 (11), 295 (73, $[M-C_6H_5NH_2]^+$), 250 (32), 163 (26), 106 (92, $[NHCH_2C_6H_5]^+$), 93 (100), 91 (100, $[C_7H_7]^+$), 83 (70), 77 (49).

(5aSR,8aRS,9SR)-1,2,4,5,5a,6,8a,9-Octahydro-1-isopropyl-3-methyl-4-phenylpyrrolo-[2,3,4-de]chinoline-2,5-dione (*rac*-**5**). To a soln. of *rac*-**3a** (0.5 g, 1.47 mmol) in MeOH (25 ml) was added dropwise at r.t. TFA (2.5 ml). After stirring the reaction mixture for 24 h, TFA (1 ml) was further added and stirring was continued for 4 h. After this time conc. HCl (15 drops) was added and stirring continued for 60 h. After evaporation of the solvent and FC of the crude product with AcOEt on 25 g of silica gel, the product was dissolved in AcOEt (20 ml) and washed with 1M aq. $NaHCO_3$ soln. (3 x 10 ml). After drying of the org. phase with Na_2SO_4, the solvent was removed and the light brown residue was crystallized from AcOEt/hexane to yield *rac*-**5** (0.37 g, 78%) as white crystals. M.p. 168°.

IR (KBr): 2980, 2930, 1735, 1660, 1635, 1615, 1495, 1430, 1385, 1375, 1325, 1230, 1215, 1190, 1155, 1135, 1070, 770, 750, 730, 700, 675, 655, 580. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.46–7.20 (*m*, 5 arom. H); 5.97 (*ddt*, *J* = 10.0, 6.8, 2.8, H–C(7)); 5.70 (*m*, *J* = 10.0, H–C(8)); 5.04 (*sept.*, *J* = 6.8, H–C(1')); 4.06 (*m*, H–C(8a)); 3.58 (*m*, H–C(9)); 3.14 (*dt*, *J* = 10.0, 1.9, H–C(5a)); 2.30 (*m*, H_a–C(6)); 1.96 (*ddq*, *J* = 17.3, 10.0, 2.8, H_b–C(6)); 1.25 (*d*, *J* = 1.8, CH_3–C(3)); 1.25, 1.20 (2*d*, *J* = 6.8, CH_3(2'), CH_3(3')). ^{13}C-NMR (90 MHz, $CDCl_3$): 179.5 (*s*, C(2)); 167.6 (br. *s*, C(5)); 147.4 (*s*, C(3a)); 135.4, 131.4, 129.2, 128.6, 127.5, 127.4 (*s* and 5 *d*, arom. or olef.) 103.4 (*s*, C(3)); 46.4, 45.3 (2*d*, C(1'), C(8a)); 38.2 (*d*, C(9)); 36.9 (*d*, C(5a)); 23.4 (*t*, C(6)); 21.3, 19.8 (2*q*, C(2'), C(3')); 11.4 (*q*, CH_3–C(3)). MS: 323 (13, [*M* + 1]$^+$), 322 (55, *M*$^+$), 321 (10), 307 (21), 279 (47), 266 (17), 236 (13), 212 (21), 202 (11), 167 (48), 149 (100), 113 (13), 104 (8), 97 (7), 83 (14), 77 (16), 71 (28), 57 (48). Anal. calc. for $C_{20}H_{22}N_2O_2$ (322.41): C 74.51, H 6.88, N 8.69; found: C 74.46, H 6.88, N 8.59.

*(3*RS*,4a*SR*,8a*RS*)-1,2,3,4,4a,5,6,8a-Octahydro-1-isopropyl-3-methylchinoline-2,4-dione* (*rac*-**6a**). To the soln. of **2a,** which was prepared from **1a** (2.2 g, 13.2 mmol; see above), was added dropwise freshly distilled acryloyl chloride (2.14 ml, 26.3 mmol) at –78° by means of a syringe. After addition was complete, stirring was continued for 1 h at –78° to give a white suspension. It was warmed to r.t. overnight and hydrolyzed with MeOH (30 ml). After evaporation of the solvent the residue was dissolved in $CHCl_3$ (50 ml), filtered and washed with 2M aq. HCl soln. (2 x 20 ml) and with sat. aq. NaCl soln. (20 ml). The org. phase was dried over Na_2SO_4 and the solvent was removed to give 9.7 g of a dark brown oil. It was flash chromatographed with AcOEt/hexane (1:1) over 50 g of silica gel to give *rac*-**6a** (yellow oil, 3.1 g, 60%) which was crystallized from $CHCl_3$/hexane (white powder). M.p. 80–81°. IR (KBr): 3040, 2980, 2940, 2870, 1710, 1645, 1465, 1450, 1430, 1365, 1325, 1260, 1210, 1070, 1055, 1015, 935, 830. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.85 (*m*, *J* = 10.3, H–C(7)); 5.57 (*m*, *J* = 10.3, H–C(8)); 4.95 (*sept.*, *J* = 6.9, H–C(1')); 4.25 (*m*, H–C(8a)); 3.47 (*q*, *J* = 6.8, H–C(3)); 2.47 (*m*, H–C(4a)); 2.42 (*m*, H_a–C(5)); 1.93 (*m*, H_a–C(6), H_b–C(6)); 1.84 (*m*, H_b–C(5)); 1.25 (*d*, *J* = 6.8, CH_3–C(3)); 1.22, 1.10 (2*d*, *J* = 6.9, CH_3(2'), CH_3(3')). ^{13}C-NMR (90 MHz, $CDCl_3$): 208.3 (*s*, C(4)); 167.4 (*s*, C(2)); 131.3 (*d*, C(7)); 127.6 (*d*, C(8)); 51.7 (*d*, C(8a)); 47.8 (*d*, C(3)); 45.8 (*d*, C(4a)); 44.8 (*d*, C(1')); 24.2 (*t*, C(5)); 20.8 (t, C(6)); 20.2, 19.9 (2*q*, C(2'), C(3')); 8.1 (*q*, CH_3–C(3)). MS: 221 (54, *M*$^+$), 206 (31), 178 (15), 167 (10), 126 (17), 107 (14), 98 (20), 80 (60), 79 (17), 70 (29), 58 (100), 44 (17). Anal. calc. for $C_{13}H_{19}NO_2$ (221.32): C 70.56, H 8.65 N 6.33; found: C 70.50, H 8.75, N 6.38.

*(3*RS*,4a*SR*,8a*RS*)-1,2,3,4,4a,5,6,8a-Octahydro-1-isopropyl-3-phenylchinoline-2,4-dione* (*rac*-**6c**). Analogous procedure to *rac*-**6a**. Starting from **2c**, which was synthesized from **1c** (3.02 g, 13.2 mmol) (see above), *rac*-**6c** (yellow oil, 2.4 g, 64%) was obtained, which could be crystallized from $CHCl_3$/hexane. M.p. 66–68°. IR ($CHCl_3$): 3038, 3000, 2978, 2923, 1728, 1650, 1495, 1460, 1430, 1385, 1365, 1320, 1290, 1255, 1195, 1125, 1070. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.53–7.03 (*m*, 5 arom. H); 5.96–5.92 (*m*, H–C(7)); 5.73–5.68 (*m*, H–C(8)); 4.96 (*sept.*, *J* = 6.8, H–C(1')); 4.65 (*s*, H–C(3)); 4.38–4.33 (*m*, H–C(8a)); 2.75–2.69 (*m*, H–C(4a)); 2.50–2.42 (*m*, H_a–C(5)); 2.07–2.00 (*m*, H_a–C(6), H_b–C(6)); 1.93–1.86 (*m*, H_b–C(5)); 1.27, 1.21 (2*d*, *J* = 6.8, CH_3(2'), CH_3(3')). ^{13}C-NMR (90 MHz, $CDCl_3$): 205.9 (*s*, C(4)); 166.0 (*s*, C(2)); 133.1, 131.6, 130.4, 128.1, 127.5, 127.3 (*s* and 5*d*, arom. or olef.); 53.6 (*d*, C(8a)); 48.0 (*d*, C(3)); 46.3 (*d*, C(4a)); 45.3 (*d*, C(1')); 23.7 (*t*, C(5)); 20.8 (*t*, (C(6)); 21.1, 20.0 (2*q*, C(2'), C(3')). MS: 283 (14, *M*$^+$), 198 (12, [*M*–C_4H_7NO]$^+$), 145 (4), 119 (9), 118 (100, [C_8H_8O]$^+$), 90 (19), 89 (10).

Methyl rac-trans-*2-(*N-*Acetyl*-N-*isopropyl-amino)cyclohex-3-ene-1-carboxylate* (*rac*-**8**) *and Methyl* 2 rac-cis-*2-(*N-*Acetyl*-N-*isopropylamino)cyclohex-3-ene-1-carboxylate* (*rac*-**9**). The pure dienamide **7** (0.26 g, 1.65 mmol) was dissolved in CH_2Cl_2 (30 ml) and freshly distilled acryloyl chloride (0.28 ml, 3.3 mmol) was added dropwise within 1 h at 0° by means of a syringe. After the addition was complete, stirring was continued overnight at 0° to give a yellow soln. The mixture was hydrolyzed with MeOH (20 ml) and the solvents were evaporated. The brown residue was dissolved in $CHCl_3$ (30 ml) and washed with 1M aq. HCl soln. (20 ml), sat. aq. $NaHCO_3$ soln. (20 ml), and sat. aq. NaCl soln. (2 x 20 ml). The org. phase was dried over Na_2SO_4 and the solvent was evaporated to give a yellow brown oil. FC with AcOEt/hexane 1:1 over 80 g of silica gel furnished the less polar *trans*-product *rac*-**8** (oil, 62 mg, 16%). IR ($CHCl_3$): 2975, 2940, 1730, 1630, 1435, 1370, 1340, 1305, 1280, 1240, 1200, 1170, 1130, 1030. ^{1}H-NMR (400 MHz, $CDCl_3$): The signals of two rotamers were obtained in a ratio of 75:25. *Rotamer A*: 5.93 (*m*, *J* = 10.2, H–C(4)); 5.51 (*dq*, *J* = 10.1, 2.1, H–C(3)); 4.66 (br. *s*, H–C(2)); 3.70 (*s*, CH_3O); 3.17 (br. *m*, H–C(1')); 2.71 (br. *m*, H–C(1)); 2.13 (*s*, CH_3(10)); 2.04 (*m*, CH_2(5)); 1.85 (*m*, CH_2(6)); 1.38 (*d*, *J* = 6.6, CH_3(2'), CH_3(3')). Further signals which were attributed to the *Rotamer B* were found at: 5.79, 5.39, 4.66, 3.87, 3.64, 1.25, 1.24. ^{13}C-NMR (100 MHz, $CDCl_3$): *Rotamer A*: 175.4 (C(7)); 171.4 (C(9)); 131.6 (C(4)); 127.9 (C(3)); 58.6 (C(2)); 52.6 (CH_3O); 48.6 (C(1')); 45.0 (C(1)); 26.7 (C(5)); 24.8 (C(6)); 24.2 (C(10)); 21.3, 21.1 (C(2'), C(3')). Further signals of the *Rotamer B* at 129.6, 128.8, 53.6, 52.4, 43.0, 34.8, 24.5, 24.3, 22.3, 21.9. MS: 240 (5, [*M* + 1]$^+$), 239 (10, *M*$^+$), 224 (1, [*M* – CH_3]$^+$), 208 (5, [*M* + 1 – OCH_3]$^+$), 197 (12), 196 (87, [*M* – C_3H_7]$^+$), 180 (4, [*M* – $COOCH_3$]$^+$), 164 (12, [*M* – $COOCH_3$ – CH_3]$^+$), 154 (93, [*M* – C_3H_7 – $COCH_3$]$^+$), 139 (13), 122 (37), 111 (64), 107 (33), 102 (25), 96 (60), 79 (65), 43 (100).

The *cis*-product *rac*-**9** was obtained (oil, 180 mg, 46%), which could be crystallized from $CHCl_3$/hexane to give white crystals. M.p. 79–80°. IR ($CHCl_3$): 2975, 2920, 2900, 1735, 1630, 1440, 1390, 1305, 1280, 1240, 1050, 880. ^{1}H-NMR (400 MHz, $CDCl_3$): The signals of two rotamers were obtained in a ratio of 72:28 . *Rotamer A*: 6.07 (*m*, H–C(4)); 5.65 (*m*, *J* = 10.0, H–C(3)); 4.63 (br. *s*, H–C(2)); 3.70 (*s*, 3 H, CH_3O); 3.50 (*m*, H–C(1')); 2.86 (*m*, H–C(1)); 2.31 (br. *d*, H_a–C(5)); 2.17 (*s*, CH_3(10)); 2.07 (*m*, H_b–C(5)); 1.96 (*m*, CH_2(6)); 1.37, 1.27 (2 *d*, *J* = 6.8, CH_3(2'), C(3')). Signals which were attributed to the *Rotamer B* were found at 6.00, 5.60, 5.22, 3.98, 1.42. ^{13}C-NMR (100 MHz, $CDCl_3$): *Rotamer A*: 173.6 (C(7)); 171.8 (C(9)); 132.5 (C(4)); 125.5 (C(3)); 53.9 (CH_3O); 52.2 (C(2)); 49.7 (C(1')); 45.5 (C(1)); 24.5 (C(5)); 24.4 (C(10)); 21.0, 20.5 (C(2'), C(3')); 20.3 (C(6)). Further signals of the *Rotamer B* at 126.4, 50.6, 48.2, 44.4, 34.5, 23.3, 22.2, 22.0. MS: 239 (12, *M*$^+$), 196 (93, [*M* – C_3H_7]$^+$) 195 (38), 164 (12), 154 (94, [*M* – C_3H_7 – $COCH_3$]$^+$), 136 (13), 122 (39), 111 (76), 102 (25), 96 (53), 95 (14), 79 (56), 69 (17), 55 (20), 43 (100). Anal. calc. for $C_{13}H_{21}NO_3$ (239.31): C 65.25, H 8.85, N 5.85; found: C 65.30, H 8.91 N 5.72.

Methyl rac-trans-*2-(*N-*Propionyl*-N-*isopropyl-amino)cyclohex-3-ene-1-carboxylate* (*rac*-**10**) *and Methyl* rac-cis-*2-(*N-*Propionyl*-N-*isopropylamino)cyclohex-3-ene-1-carboxylate* (*rac*-**10**). Analogously to the transformation of **7** to *rac*-**8** and *rac*-**9** , *rac*-**10** and *rac*-**11** were prepared from **1a** (0.26 g, 1.65 mmol). In this manner *rac*-**10** was obtained (oil, 93 mg, 16%). IR ($CHCl_3$): 3015, 3000, 2959, 2949, 1730, 1630, 1440, 1380, 1340, 1280, 1240, 1200, 1170, 1130, 1120, 1070, 1040, 960. ^{1}H-NMR (400 MHz, $CDCl_3$): The signals of two rotamers were obtained in a ratio of 67:33. *Rotamer A*: 5.92 (*m*, H–C(4)); 5.50 (dq, *J* = 10.2, 1.7, H–C(3)); 4.72 (br. *d*, H–C(2)); 3.68 (*s*, CH_3O); 3.18 (*m*, *J* = 6.8, H–C(1')); 2.72 (*m*, H–C(1)); 2.35 (*dq*, CH_2(10)); 2.15–1.83 (*m*, CH_2(5), CH_2(6)); 1.39 (2*d*, *J* = 6.6, CH_3(2'), CH_3(3')); 1.11 (*dt*, CH_3(11)). Signals which were attributed to the *Rotamer B* were found at 5.80, 5.40, 3.95, 3.63, 1.22. ^{13}C-NMR (100 MHz, $CDCl_3$): *Rotamer A*: 175.1 (C(7)); 174.0 (C(9)); 131.3 (C(4)); 127.9 (C(3)); 56.9 (C(2)); 52.2 (CH_3O); 48.3 (C(1')); 44.7 (C(1)); 27.8 ((C(10)); 26.4 (C(5)); 24.5 (C(6)); 21.1, 21.0 (C(2'), C(3')); 9.7 (C(11)); further signals of the *Rotamer B* at 175.9, 129.7, 53.3, 51.7, 42.6, 28.6, 24.2, 22.0, 21.6, 9.9. MS: 253 (15, *M*$^+$), 196 (98, [*M* – COC_2H_5]$^+$), 167 (13), 154 (100, [*M* + 1 – C_3H_7 – COC_2H_5]), 139 (12), 111 (66), 96 (40), 79 (45), 57 (40, [COC_2H_5]$^+$), 43 (21).

Further elution furnished the more polar *cis*-product *rac*-**11** (oil, 325 mg, 56 %), which was crystallized from $CHCl_3$/hexane to give white crystalls. M.p. 45°. IR ($CHCl_3$): 2975, 2940, 1735, 1630, 1460, 1440, 1300, 1270, 1240, 1050. ^{1}H-NMR (400 MHz, $CDCl_3$): The signals of two rotamers were obtained in a ratio of 70:30. *Rotamer A*: 6.05 (*m*, H–C(4)); 5.64 (*m*, H–C(3)), 4.69 (br. *s*, H–C(2)); 3.68 (*s*, CH_3O); 3.49 (br. *s*, H–C(1')); 2.83 (*m*, H–C(1)); 2.54–2.39 (*m*, CH_2(10)); 2.06-1.79 (*m*, CH_2(5), CH_2(6)); 1.38 , 1.24 (2*d*, *J* = 6.8, CH_3(2'), CH_3(3')); 1.11 (*t*, CH_3(11)). Signals which were attributed to the *Rotamer B* were found at 5.95, 5.55, 4.0, 3.61, 1.23. ^{13}C-NMR (100 MHz, $CDCl_3$): *Rotamer A*: 174.8 (C(1')); 173.6 (C(9)); 132.4 (C(4)); 125.6 (C(3)); 52.4 (C(2)); 52.1 (CH_3O); 49.7 (C(1')); 45.5 (C((1)); 28.4 (C(10)); 24.4 (C(5)); 21.3, 20.6 (C(2'), C(3')); 20.3 (C(6)); 9.9 (C(11)). Signals of the *Rotamer B* at 175.5, 174.4, 131.5, 126.9, 57.1, 52.5, 45.0, 29.3, 28.2, 24.8, 9.9. MS: 253 (12, *M*$^+$), 196 (43, [M – COC_2H_5]$^+$), 167 (15), 154 (100, [*M* + 1 – C_3H_7 – COC_2H_5]$^+$), 138 (13), 116 (25), 111 (81), 96 (48), 79 (49), 57 (39, [COC_2H_5]$^+$), 43 (22). Anal. calc. for $C_{14}H_{23}NO_3$ (253.34): C 66.37, H 9.15, N 5.53; found: C 66.30, H 9.05, N 5.43.

Methyl rac-trans-2-*(*N-*Acetyl*-N-*isopropyl-amino)cyclohexane-1-carboxylate* (*rac*-**12**). A 10-ml autoclave was charged with *rac*-**8** (100 mg, 0.42 mmol) and 10% Pd/C (60 mg, 0.06 mmol) and EtOH (5ml). The autoclave was secured with H_2 (3x) and shaken overnight under 5–6 bar H_2 pressure. The catalyst was then removed by filtration over *Celite* and washed with EtOH (50 ml). Evaporation of the filtrates and FC with

AcOEt/hexane 1:1 of the residue provided *rac*-**12** (72 mg, 71%) as a colorless oil. IR (CCl_4): 2995, 2935, 2860, 1740, 1650, 1430, 1380, 1300, 1170, 1130, 1025, 940. ^{1}H-NMR (400 MHz, $CDCl_3$): 3.81 (*dt*, *J* = 11.8, 3.8, H–C(2)); 3.66 (*s*, CH_3O); 3.27 (*sept.*, *J* = 6.8, H–C(1')); 2.61 (*dt*, *J* = 11.5, 3.7, H–C(1)); 2.15 (*s*, CH_3(10)); 2.11–1.42 (*m*, CH_2(6), CH_2(3), CH_2(5), CH_2(4)); 1.37, 1.34 (2*d*, *J* = 6.8, CH_3(2'), CH_3(3')). ^{13}C-NMR (100 MHz, $CDCl_3$): 175.3 (C(7)); 171.3 (C(9)); 60.1 (C(2)); 52.3 (CH_3O); 47.7 (C(1')); 47.6 (C(1)); 31.0, 30.9, 26.1, 25.4 (C(3), C(6), C(5), C(4)); 24.3 (C(10)); 21.5, 21.1 (C(2'), C(3')). MS: 242 (9, [*M* + 1]$^+$), 241 (8, *M*$^+$), 210 (16, [*M* – OCH_3]$^+$), 198 (77, [*M* + 1 – OCH_3 – CH_3]$^+$), 184 (55), 166 (27), 156 (34), 126 (38), 102 (100, [$C_5H_{10}NO$]$^+$), 98 (84), 86 (31), 43 (29).

Methyl rac-cis-2-*{*N-*Acetyl*-N-*isopropylamino}cyclohexane-1-carboxylate* (*rac*-**13**). Analogously to the transformation of *rac*-**8** to *rac*-**12**, *rac*-**13** was prepared from *rac*-**9** (100 mg, 0.42 mmol): colorless oil (80 mg, 79%). IR (CCl_4): 3010, 2975, 2930, 2895, 2850, 1730, 1630, 1450, 1390, 1245, 1190, 1160, 1130, 1045, 910. ^{1}H-NMR (400 MHz, ((D$_6$)DMSO, 373 K): 3.87 (*sept.*, *J* = 6.8, H–C(1')); 3.77 (*dt*, *J* = 12.0, 3.9, H–C(2)); 3.69 (*s*, CH_3O); 2.91 (br. *s*, H–C(1)); 2.62 (*m*, H_b–C(4)); 2.11 (*s*, CH_3(10)); 1.97–1.41 (*m*, CH_2(6), CH_2(3), CH_2(5), H_a–C(4)); 1.37, 1.35 (2*d*, *J* = 6.8, CH_3(2'), CH_3(3')). ^{13}C-NMR (100 MHz, (D$_6$)DMSO, 373 K): 173.3 (C(7)); 168.9 (C(9)); 56.8 (C(2)); 50.3 (CH_3O); 46.8 (C(1')); 43.6 (C(1)); 28.2, 25.9, 25.3 (C(3), C(4), C(5)); 22.7 (C(10)); 20.6, 20.5 (C(2'), C(3')); 19.9 (C(6)). MS: 242 (9, [*M* + 1]$^+$), 241 (8, *M*$^+$), 210 (18, [*M* – OCH_3]$^+$), 198 (61, [*M* + 1 – OCH_3 – CH_3]$^+$), 184 (40), 166 (15), 156 (32), 140 (21), 126 (92), 102 (46), 98 (100), 86 (24), 81 (30), 70 (23), 56 (20), 43 (50).

Methyl rac-cis-2-*{*N-*Isopropyl*-N-*{1-[(trimethylsilyl)oxy]ethenyl}amino}cyclohex-3-ene-1-carboxylate* (*rac*-**14**). In a oven dried NMR tube, a soln. of *rac*-**9** (30 mg, 0.13 mmol) in $CDCl_3$ (1.5 ml), which was filtered twice over basic Al_2O_3, and HMDS (45 mg, 0.3 mmol) was prepared. To this soln. was added dropwise at r.t. TMSI (30 mg, 0.15 mmol), by means of a syringe to give a yellow soln. from which a white salt precipitated. After standing for 2 h the mixture was analyzed by ^{1}H-NMR, wherein *rac*-**14** was *obtained* in >95% yield. ^{1}H-NMR (400 MHz, $CDCl_3$): 6.30 (*m*, H–C(3), H–C(4)); 5.37 (br. *s*, H–C(2)); 4.09 (*m*, *J* = 6.6, H–C(1')); 3.71 (*s*, CH_3O); 3.27 (*m*, H–C(1)); 3.03 (*s*, CH_2(10)); 2.32, 2.17 (2*m*, CH_2(5), CH_2(6)); 1.44, 1.34 (2*d*, *J* = 6.7, CH_3 (2'), CH_3(3')); 0.05 (*s*, $(CH_3)_3Si$).

*(4a*SR,*8a*RS*)-1,2,3,4,4a,5,6,8a-Octahydro-1-isopropylchinoline-2,4-dione* (*rac*-**15**). A 2 flame-dried 50-ml three-necked flask fitted with magnetic stirrer, septum, thermometer and N_2 bubbler was flushed with N_2. The flask was charged with anh. $(i\text{-}Pr)_2NH$ (0.15 ml, 1.0 mmol) and THF (10 ml). A 1.6M soln. of BuLi (hexane, 0.49 ml, 0.8 mmol) was added dropwise within 30 min at –78° by means of a syringe. After stirring the mixture for 30 min at 0°, the resulting LDA-soln. was cooled to –78°. Slow addition of a soln. of *rac*-**9** (135 mg, 0.57 mmol) in THF (3 ml) at –85°, stirring of the mixture at the same temp. for 3 h gave a light yellow soln. It was warmed up overnight to r.t. and poured onto sat. aq. NH_4Cl/ice soln. and extracted with Et_2O (2 x 100 ml). The org. phase was washed with sat. aq. $NaHCO_3$ soln. (20 ml) then with sat. aq. NaCl soln. (2 x 30 ml). Drying over Na_2SO_4, evaporation of the solvent and FC with AcOEt/hexane 1:1 over 100 g of silica gel gave methyl cyclohexa-1,3-diene-1-carboxylate (**16**) [24] as a yellow oil (11 mg, 14%).

Further elution furnished the more polar *rac*-**15** as a yellow oil, which could be crystallized from $CHCl_3$/hexane to give clear white crystals (30 mg, 26%). M.p. 94–95°. IR ($CHCl_3$): 2980, 2915, 2900, 1725, 1640, 1450, 1390, 1250, 1050, 880. ^{1}H-NMR (400 MHz, $CDCl_3$): 5.82 (*m*, *J* = 10.2, H–C(7)); 5.59 (br. *d*, *J* = 10.2, H–C(8)); 4.98 (*sept.*, *J* = 6.9, H–C(1')); 4.26 (br. *s*, H–C(8a)); 3.44 (*d*, *J* = 19.2, H_a–C(3)); 3.21 (*d*, *J* = 19.2, H_b–C(3)); 2.51 (*m*, H–C(4a)); 2.45 (*m*, H_a–C(5)); 1.97 (*m*, H_a–C(6), H_b–C(6)); 1.81 (*m*, H_b–C(5)); 1.23, 1.16 (2*d*, *J* = 6.9, CH_3(2'), CH_3(3')). ^{13}C-NMR (100 MHz, $CDCl_3$): 206.8 (C(4)); 166.4 (C(2)); 132.0 (C(7)); 128.8 (C(8)); 49.5 (C(8a)); 49.2 (C(3)); 47.2 (C(4a)); 45.2 (C(1')); 23.5 (C(5)); 21.5 (C(6)); 20.9, 20.7 (C(2'), C(3')). MS: 208 (62, [*M* + 1]$^+$), 207 (40, *M*$^+$), 193 (22), 164 (17), 112 (16), 107 (22), 96 (18), 79 (75), 77 (59), 70 (100).

X-Ray Crystal-Structure Determination of rac-**15**. $C_{12}H_{17}NO_2$, M_r = 207.3, monoclinic, $P2_1/c$, *a* = 11.514(2), *b* = 8.594(2), *c* = 12.671(3) Å, *V* = 1129.3 Å^3, *Z* = 4, D_x = 1.219 g·cm^{-3}, *l* = 0.71073 Å, *m* = 0.8 cm^{-1}, *F*(000) = 448. 1991 unique reflections, 1164 observed [*I*>2s(*I*)], *R* = 0.061, R_w = 0.081, *k* = 0.002, *S* = 1.45. Max shift/sigma ratio 0.001, residual density(e/Å^3) max. 0.18, min –0.18. Intensity data were collected at r.t. on a *Stoe AED2* 4-circle diffractometer using MoK_α graphite monochromated radiation using the Θ/2Θ scan mode. The crystal exhibited a large mosaic spread of at least 1.5°. The structure was solved by direct methods using the programme SHELXS-86 [25]. All further calculations were carried out using the NRCVAX [26] system. Neutral complex-atom scattering factors in NRCVAX [27] are from [27]. The H-atoms were included in calculated positions; initally refined for two rounds then held fixed. The non-hydrogen atoms were refined anisotropically using weighted full-matrix least-squares, where $w = 1/[\sigma^2(F_o) + k(F_o^2)]$. Atomic parameters and complete tables of bond distances and angles have been deposited with the Cambridge Crystallographic Data Centre, Union Road, Cambridge CB2 1EZ, England. The *Figure* illustrates the numbering scheme used and was drawn using the programme ORTEP-II [28]. Further details may be obtained from the author *H. St-E.*

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