Mono- and Disubstituted *N,N*-Dialkylcyclopropylamines from Dialkylformamides via Ligand-Exchanged Titanium – Alkene Complexes**

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Dedicated to Professor Hans Paulsen on the occasion of his 80th birthday

Abstract: Dibenzylformamide was treated with cyclohexylmagnesium bromide in the presence of either titanium tetraisopropoxide or methyltitanium triisopropoxide and a variety of cyclic and acyclic alkenes and alkadienes to give new mono- and disubstituted as well as bicyclic dialkylcyclopropylamines (Tables 1 – 3) in yields ranging from 18 to 90% (in most cases around 55%). 3-Benzyl-6-(*N,N*-dibenzylamino)-3-azabicyclo[3.1.0]hexane (**10a**) and the orthogonally bisprotected 3-*tert*-butoxycarbonyl-6-(*N,N*-dibenzyl)-3-azabicyclo[3.1.0]hexane (**10d**) as well as the analogous 6-(*N,N*-dibenzylamino)bicyclo[3.1.0]hexane (**12**) were obtained as pure *exo* diastereomers in particularly high yields (87, 90, and 88%, respectively) from *N*-benzylpyrroline (**15a**), *N*-Boc-pyrroline (**15d**; Boc = *tert*-butyloxycarbonyl) and cyclopentene (**19**). 1,3-Butadiene (**52**) and substituted 1,3-butadienes were also aminocyclopropanated quite well to give 2-ethenylcyclopropylamines in good yields (51 – 64%). Except for alkenyl- and aryl-substituted compounds, *N,N*-dibenzylcyclopropylamines can be debenzylated by catalytic hydrogenation to the primary cyclopropylamines as demonstrated for **10a** and **10d** to yield the fully deprotected **10e** (93%) and mono-Boc-protected **10f** (98%), respectively. The latter are interesting templates for combinatorial syntheses of libraries of small molecules with a well defined distance of 4.3 Å between two nitrogen atoms.

Keywords: amines · cyclopropanation · cyclopropylamines · N ligands · titanium · transition metals

Introduction

The aminocyclopropyl moiety plays a significant role in a variety of naturally occurring amino acids[1] and quite a number of biologically active non-natural compounds.[2] Three convincing examples are the antidepressant Tranylcypromine (**1**)[3] as well as the two broad-spectrum antibacterials Ciprofloxacin (**2**),[4] and Trovafloxacin (**3**)[5] which are actual commercially available drugs. There are only a few reasonably general routes to cyclopropylamines,[6] the classical ones being Hofmann (or an analogous) degradation of a carboxylic acid derivative,[7] γ-elimination on a C_3 fragment containing a halogen (or other good leaving group) and a C-H-acidifying amino group equivalent,[7, 8] as well as the more recently reported reductive amination of a cyclopropanone equivalent (acetal or hemiacetal).[9] These processes can be quite tedious or not viable for certain cyclopropylamines. Our recently developed titanium-mediated cyclopropanation of *N,N*-dialkylcarboxamides,[10, 11] an adaptation of the Kulinkovich protocol for the conversion of esters to cyclopropanols,[12] is more general and conveniently applicable towards the synthesis of a large variety of 1- and 2-substituted, 1,2-, 2,2-, and

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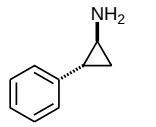
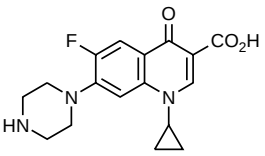
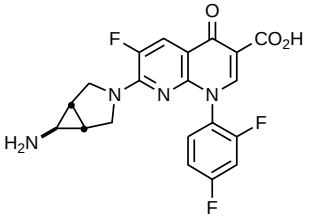


1, Tranylcypromine

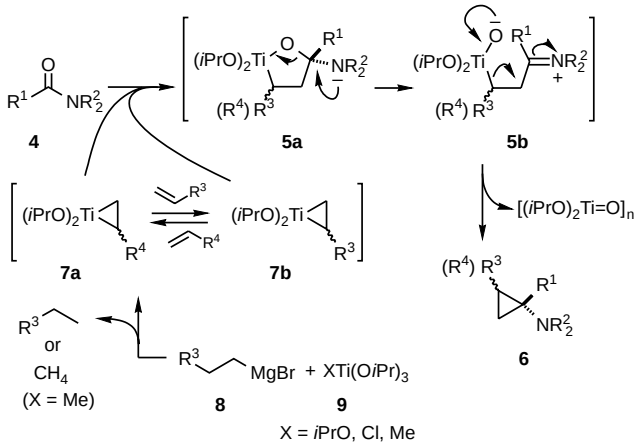


2, Ciprofloxacin



3, Trovafloxacin

2,3-disubstituted as well as 1,2,2- and 1,2,3-trisubstituted cyclopropylamines. One obvious limitation of this method, however, can arise from the unavailability of a suitably substituted Grignard reagent **8** which is required to generate the titanacyclopropane reactive intermediate **7** that actually transfers the two-carbon fragment to the acid dialkylamide **4** (Scheme 1). This difficulty, though, can be overcome by the

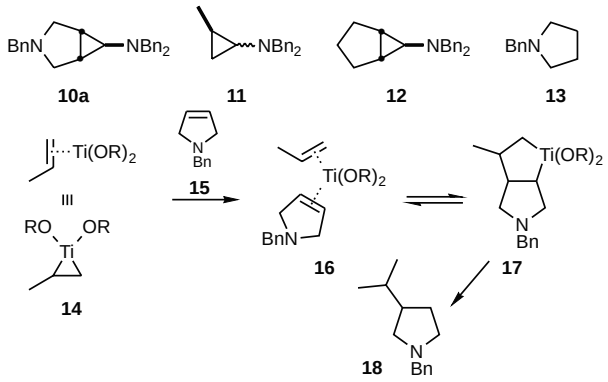


Scheme 1.

possibility of generating the appropriately substituted titanacyclopropane intermediate **7a** from another one **7b**, prepared by the Grignard route, by alkene–ligand exchange, as was first shown by Kulinkovich et al. for styrene in the preparation of phenyl-substituted cyclopropanols,[13] and later applied by Sato et al.[14] as well as Cha et al.[15, 16] The latter authors favor the use of commercially available cyclopentylmagnesium chloride which yields a 2-titanabicyclo[3.1.0]hexane, corresponding to a titanium–cyclopentene complex, that rapidly undergoes ligand exchange with monosubstituted alkenes.[15b] In view of the importance of more highly substituted cyclopropylamines such as *exo*-6-amino-3-azabicyclo[3.1.0]hexane (**10e**) which is an essential fragment in Trovafloxacin (**3**), we embarked on a project to develop improved conditions for the cyclopropanation of acid dialkylamides via titanacyclopropane reactive intermediates generated by alkene–ligand exchange.

Results and Discussion

Initial attempts were made with styrene (**38a**) and 1,3-butadiene (**52**) following the original protocol of Kulinkovich et al.[13] using ethylmagnesium bromide and $[Ti(OiPr)_4]$. The correspondingly substituted cyclopropylamines **39a**, **53** derived from *N,N*-dibenzylformamide were obtained, albeit in unsatisfactory yields. According to Sato et al., propene–titanium intermediates generated from $[XTi(OiPr)_3]$ (X = iPrO, Cl) and isopropylmagnesium halides undergo ligand exchange more rapidly than the parent ethylene–titanium complex.[14] Therefore, the use of isopropylmagnesium bromide in diethyl ether and in tetrahydrofuran in the presence of $[Ti(OiPr)_4]$ was tested for the ligand exchange with *N*-benzylpyrroline (**15a**) and subsequent aminocyclopropanation with *N,N*-dibenzylformamide. Indeed, *exo*-6-(dibenzylamino)-3-benzyl-3-azabicyclo[3.1.0]hexane (**10a**) was obtained in both cases, yet **10a** was always accompanied by equal amounts of a mixture of *cis*- and *trans*-2-methyl-*N,N*-dibenzylcyclopropylamine (**11**), apparently formed by direct attack of the propene–titanium complex on the formamide. When **15a** was treated with isopropylmagnesium bromide in the presence of $[Ti(OiPr)_4]$ and *N,N*-dibenzylformamide at room temperature, it gave, in addition to **10a** and **11**, *N*-benzyl-3-isopropylpyrrolidine (**18**) in large proportions (Scheme 2).



Scheme 2.

The latter was the major product (up to ca. 50% yield) when this same reaction was carried out in the absence of *N,N*-dibenzylformamide. This type of reductive coupling of an alkene–titanium intermediate to another alkene has literature precedence and was first described as an ethylene dimerization reaction.[17, 18]

Far better yields of the trisbenzyl-protected bicyclic diamine **10a** were obtained by using a cyclohexylmagnesium halide (chloride or bromide).[15b] Optimization of all the parameters for the reaction conditions (solvent, temperature, nature of the titanium species, excess of Grignard reagent) was eventually achieved and gave **10a** as the pure *exo* diastereomer in up to 87% yield (Table 1, entry 1) without any other cyclopropylamine side product.[19] The configuration of **10a** was unequivocally proved by an X-ray crystal structure analysis of the debenzylated diamine **10e** (see Figure 1).[20] Unreacted *N*-benzylpyrroline (**15a**) and *N,N*-dibenzylforma-

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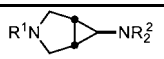
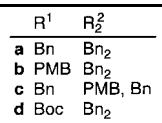
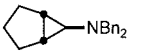
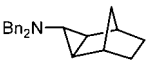
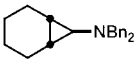
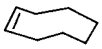
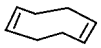
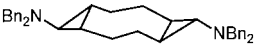
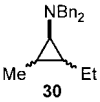
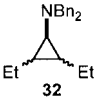
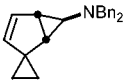
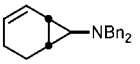
Table 1. *N,N*-Dibenzylcyclopropylamines from *N,N*-dibenzylformamides and 1,2-disubstituted alkenes via ligand-exchanged titanacyclopropane intermediates.

Entry	Alkene	Conditions[a]	Product	Yield [%]	d.r. (*cis/trans* or *endo/exo*)
1	 **15**	A	 **10** 	87	<2:98
2		E		68	<2:98
3		E		67	<2:98
4		A		90	<2:98
5	 **19**	B	 **12**	28	<2:98
		C		88[b]	<2:98
6	 **20**	B	 **21**	43	<2:98
7	 **22**	C	 **23**	27	<2:98
8	 **24**	C	 **25**	33[c]	<2:98
9	 **26**	A	 **27**	11	<2:98
		B	 **28**	1.5	<2:98
10	 **29**	A	 **30**	26	1:2:6
11	 **31**	A	 **32**	13	1:14:15
12	 **33**	B	–	–	–
13	 **34**	A	 **35**	trace	–
14	 **36**	B	 **37**	58	<2:98

[a] Under all conditions 1.0 equivalent of the respective formamide was used. A: alkene/diene and $[Ti(OiPr)_4]$ (1.1 equiv), MeMgCl (or MeMgBr) and *c*HexMgBr (1.2 equiv). B: alkene/diene and $[Ti(OiPr)_4]$ (1.0 equiv), *c*HexMgBr (2.0–2.5 equiv). C: cycloalkene and $[Ti(OiPr)_4]$ (1.0 equiv), *c*HexMgBr (3.1 equiv). E: alkene (1.0 equiv), $[Ti(OiPr)_4]$ (1.01 equiv), *c*HexMgBr (3.33 equiv). [b] cC_5H_9MgBr was used instead of *c*HexMgBr. [c] $cC_8H_{15}MgBr$ was used instead of *c*HexMgBr.

mide could easily be removed by filtration through a pad of silica gel and/or short path distillation under reduced pressure. The partially *p*-methoxybenzyl-protected analogues of **10a**, the bicyclic diamines **10b**,**c** could also be prepared according to the same protocol from *N*-(*p*-methoxybenzyl)pyrroline (**15b**) and dibenzylformamide or *N*-benzylpyrroline (**15a**) and *N*-benzyl-*N*-(*p*-methoxybenzyl)formamide, respectively (Table 1, entries 2, 3). An even better result was achieved with *N*-(*tert*-butoxycarbonyl)pyrroline[21] (**15c**) giving the synthetically useful orthogonally bisprotected diamine **10d** in 90% yield.[22, 23]

When cyclopentylmagnesium chloride, which has been favored by Cha et al.[16] in generating ligand-exchanged titanium reagents with terminal alkenes, was applied for comparison in the transformation of **15a**, three products were obtained, the expected **10a** (34%), *exo*-6-(*N,N*-dibenzylamino)bicyclo[3.1.0]hexane (**12**) (49%), apparently arising by the direct reaction of the titanium intermediate from cyclopentylmagnesium chloride (without ligand exchange), and *N*-benzylpyrrolidine (**13**) (ca. 28%) arising from formal hydrogenation of *N*-benzylpyrroline (**15a**), probably by hydrolysis of the titanacyclopropane intermediate formed from **15a**.

With the optimized protocol (that is with the use of cyclohexylmagnesium bromide and $[MeTi(OiPr)_3]$),[11] it appears that nonterminal alkenes can be used to generate ligand-exchanged titanium–alkene species that react with *N,N*-dibenzylformamide (and other *N,N*-dialkylformamides) without problems, and thus a number of other cyclic alkenes and dienes were tested (Table 1). Cyclopentene (**19**), cyclohexene (**22**), cyclooctene (**24**), and cycloocta-1,5-diene (**26**), all reacted to give the corresponding bicyclic cyclopropylamines in poorer yields (11–33%) than *N*-benzylpyrroline (**15a**) (Table 1, entries 5, 7–9); all these bicyclic cyclopropylamines were pure *exo* diastereomers, in none of the cases could the *endo* isomer be detected. The yield of *exo*-6-dibenzylaminobicyclo[3.1.0]hexane (**12**) could be increased to 88%, when cyclopentylmagnesium bromide (or chloride) in the presence of cyclopentene (**19**) was used.[24] Norbornene (**20**) with its strained double bond, and the conjugated 1,3-cyclohexadiene (**36**) gave significantly better yields of **21** and **37** (43 and 58%, respectively; Table 1, entries 6 and 14) than cyclohexene (**22**). Cycloocta-1,5-diene (**26**) afforded, in addition to 11% of the mono-aminocyclopropanation product **27**, a small amount (1.5% yield) of the twofold aminocyclopropanation product **28** as colorless crystals which could be characterized by an X-ray structural analysis as the *exo,exo*-5,10-bis(dibenzylamino)-*anti*-tricyclo[7.1.0.$0^{4,6}$]decane (**28**) (see below, Figure 1).[20] Cyclopentadiene (**33**) apparently is only deprotonated by the basic organometallic intermediates, and thus

recovered unchanged, whereas spiro[2.4]heptadiene (**34**) gave the corresponding cyclopropylamine **35** only in trace amounts. This must be due to steric hindrance of complexation at one of its double bonds by the neighboring spirocyclopropane moiety.

The acyclic nonterminal alkenes *cis*-2-pentene (**29**) and *trans*-3-hexene (**31**) could be converted to the corresponding 2,3-disubstituted cyclopropylamines **30** and **32**, albeit in low yields (26 and 13%, respectively), and without retention of the original alkene configuration (Table 1, entries 10, 11), as three diastereomers were formed in both cases.

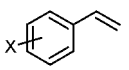
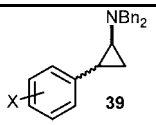
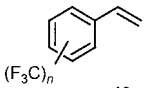
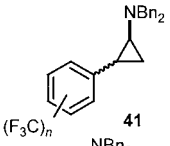
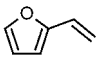
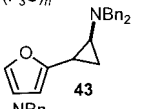
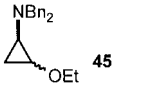
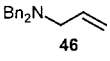
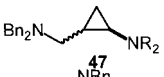
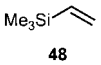
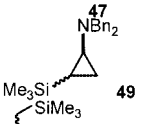
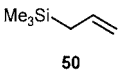
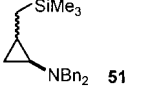
Terminal alkenes generally give better yields than open-chain internal ones. Styrene (**38a**) and substituted styrenes **38b**,**c** as well as **40a–d** (Table 2) were tested preferentially, since not only *trans*-2-phenylcyclopropylamine (**1**, Tranylcypromine)[3] is well known as a pharmacologically active compound, but a number of (2-arylcyclopropyl)urea derivatives have been shown to be particularly potent inhibitors of HIV-1 reverse transcriptase.[25] In fact, (2-phenylcyclopropyl)-*N,N*-dibenzylamine (**39a**) was obtained from styrene (**38a**) as a 1:3.1 mixture of *cis* and *trans* isomers in 66% yield. The substituted styrenes **38b**,**c** and **40a–d** were converted to the corresponding (2-arylcyclopropyl)amines **39b**,**c** and **41a–d** in 9–46% yield with the 4-methoxy- and 3-trifluoromethyl-substituted compounds giving the best results (Table 2, entries 2–7). Most probably for steric reasons, 2-bromostyrene (**38c**) only gave the *trans*-2-(2′-bromophenyl)-substituted cyclopropylamine **39c**. While 2-ethenylfuran (**42**) furnished 2-furylcyclopropylamine (**43**) in 43% yield, 2-ethenylpyridine did not react at all. Ethenyl ethyl ether (**44**) underwent aminocyclopropanation in extremely low yield (4%) (Table 2, entry 9), but allyldibenzylamine (**46**) as well as ethenyltrimethylsilane (**48**)[26] and allyltrimethylsilane (**50**) provided the correspondingly substituted cyclopropylamines **47b**, **49**, **51** in moderate to good yields (39, 59, and 28%, respectively).

Acyclic conjugated dienes with at least one terminal double bond turned out to be particularly good ligands, such as cyclohexadiene (**36**), and could rather efficiently be aminocyclopropanated to furnish 2-ethenylcyclopropylamines in moderate to good yields (up to 64%, Table 3, entries 1–8).[27]

Surprisingly, the reaction with substituted 1,3-butadienes such as isoprene (**54**), 4-methyl-1,3-pentadiene (**57**), and myrcene (**61**) all gave the alkenyldibenzylaminocyclopropanes derived from putative attack on the more highly substituted double bond of the conjugated diene unit rather than the expected product which would have been formed by attack on the least substituted double bond (Table 3, entries 2, 4, 7). As these expected products were not detected in any case, and control experiments with 2,3-dimethylbutadiene (**56**) and 2,5-dimethyl-2,4-hexadiene (**60**) did not yield any cyclopropylamine, it must be concluded that the alkenyldiisopropyloxytitanacyclopropane **67** with the least substituted double bond of the conjugated diene attached to the titanium center, is kinetically—and possibly thermodynamically—favored. The formamide then cycloadds to this alkenyltitanacyclopropane **67** by way of a metalla–ene reaction with a six-center transition state to yield an oxatitanacycloheptene **68**. This intermediate can cyclorevert to an (iminiumallyl)titanium oxide 1,8-zwitterion **69**, which subsequently can only cyclize to a cyclopentenylamine or to the observed, more highly substitued cyclopropylamine **70** (Scheme 3).[27]

The formation of the same cyclopropylamine from 2-methyl-1,3-pentadiene (**59**) as from 4-methyl-1,3-pentadiene (**57**) (entries 5, 4 in Table 3) most probably arises by initial isomerization of the former to the latter under the conditions employed. The fact that the conjugated 6-methyl-1,3,5-heptatriene (**65**) yields only the 2,3-dialkenylcyclopropylamine **66** (Table 3, entry 9), which arises from putative attack at the central double bond in **65**, may also be taken to indicate that the initially formed intermediate is actually the less substi-

Table 2. *N,N*-Dialkylcyclopropylamines from *N,N*-dialkylformamides and terminal alkenes via ligand-exchanged titanacyclopropane intermediates.

Entry	Alkene	Conditions[a]	Product		Yield [%]	d. r. (*cis/trans*)
1	 **38**	A	 **39**	**a** X = H	66	1:3.1
2		A		**b** X = 4-OMe	45	1:1.2
3		A		**c** X = 2-Br	30	< 2:98
4	 **40**	A	 **41**	**a** 2-CF_3	11[b]	1:4
5		A		**b** 4-CF_3	18	0:1
6		A		**c** 3-CF_3	46[b]	1:11.5
7		A		**d** 3,5-$(CF_3)_2$	9[b]	1:16
8	 **42**	A	 **43**		43	1:4
9	 **44**	A	 **45**		4	1:0
10	 **46**	D	 **47**	**a** R = Me **b** R = Bn	44[c] 39	1:5 1:4
11	 **48**	D	 **49**		59	0:1
12	 **50**	D	 **51**		28	0:1

[a] A: see Table 1. D: alkene/diene (1.0–1.2 equiv), [MeTi(O*i*Pr)$_3$] (1.0–1.5 equiv), *c*HexMgBr (1.5–2.4 equiv). [b] Addition of cyclohexylmagnesium bromide within 20 min. [c] *N,N*-Dimethylformamide was used instead of *N,N*-dibenzylformamide.

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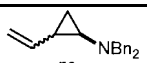
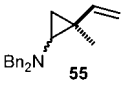
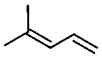
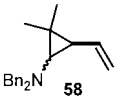
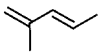
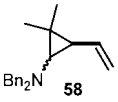
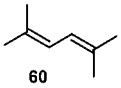
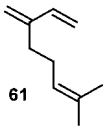
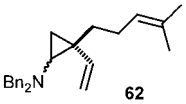
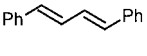
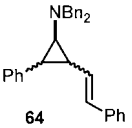
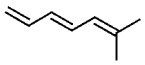
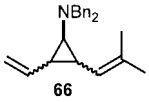
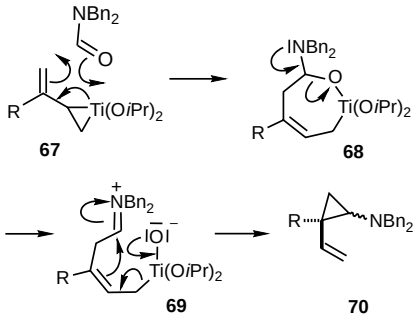
Table 3. *N,N*-Dibenzylcyclopropylamines from *N,N*-dibenzylformamides and conjugated dienes via ligand-exchanged titanacyclopropane intermediates.

Entry (*cis/trans*)	Alkene	Conditions[a]	Product	Yield	d.r. [%]
1	 **52**	D	 **53**	56	<2:98
2	 **54**	A	 **55**	59	<2:98
3	 **56**	A	–[b]	–	–
4	 **57**	A	 **58**	64	1:5.3[c]
5	 **59**	A	 **58**	27	1:3[c]
6	 **60**	A	–[b]	–	–
7	 **61**	A	 **62**	51	<2:98
8	 **63**	A	 **64**	9	1:0
9	 **65**	A	 **66**	54	1:1.5:1.5[c]

[a] A, D: see Table 1, 2. [b] No conversion of diene observed. [c] The ratio of isomers was calculated on the basis of ^{1}H NMR spectra of obtained chromatography fractions.

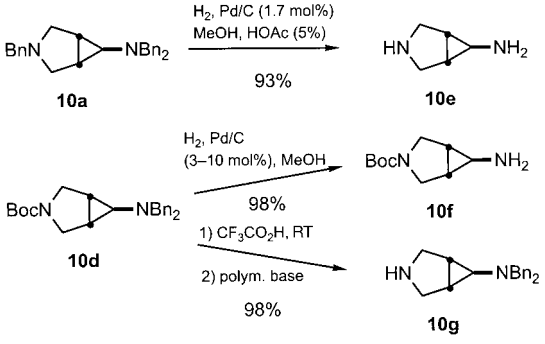


Scheme 3.

tuted titanacyclopropane of type **67**, which reacts in a metalla–ene reaction mode rather than the conceivable most highly substituted titanacyclopropane arising from coordination on the trisubstituted double bond in **65**.

In most cases, *N,N*-dibenzylformamide was used to prepare *N,N*-dibenzylcyclopropylamines, but other *N,N*-dialkylformamides can be employed as well. Except for aryl- and alkenyl-substituted compounds, *N,N*-dibenzylcyclopropylamines can be debenzylated to give the primary cyclopropylamines by catalytic hydrogenation over palladium on charcoal in methanol in the presence of 5 mol% acetic acid or 2N hydrochloric acid. No ring opening occurred, as demonstrated for the trisbenzyl-protected bicyclic diamine **10a**, to afford pure *exo*-6-amino-3-azabicyclo[3.1.0]hexane (**10e**) in excellent yield (93%) using 1.7 mol% of Pd/C catalyst (Scheme 4). Debenzylation of compounds **10a** and **10d** under neutral conditions gave diamine **10e** and mono-*N*-Boc-protected diamine **10f** in high yields (93 and 98%, respectively), but it required larger amounts of catalyst to go to completion [ca. 10 mol% of Pd/C 10%)]. On a larger scale, though, deprotection of **10d** could be carried out under neutral conditions with only 3 mol% of the Pd/C catalyst. Reaction of **10d** with trifluoroacetic acid gave the hydrotrifluoroacetate of **10g** from which the amine **10g** was liberated in 98% overall yield by treatment with a polymeric base such as poly-(4-vinylpyridine).

To rigorously prove the configuration of the bicyclic diamines **10** and to determine the influence of substituents on the two nitrogen atoms on the conformation of the skeleton, X-ray crystal structure analyses were performed on the free diamine **10e** as well as the two 3-Boc-protected derivatives **10d** and **10f** (Figure 1.)[20] In all three compounds of type **10**, the 3-azabicyclo[3.1.0]hexane skeleton adopts a flattened boat-type conformation with the nitrogen corner in the five-membered heterocycle being bent towards the cyclopropyl group. This bending angle is rather similar in **10d** (23.1°) and **10e** (27.2°), but significantly smaller (only 11.2°) in the mono-Boc-protected diamine **10f**. Consequently, the nitrogen–nitrogen distance is largest in **10f**



Scheme 4.

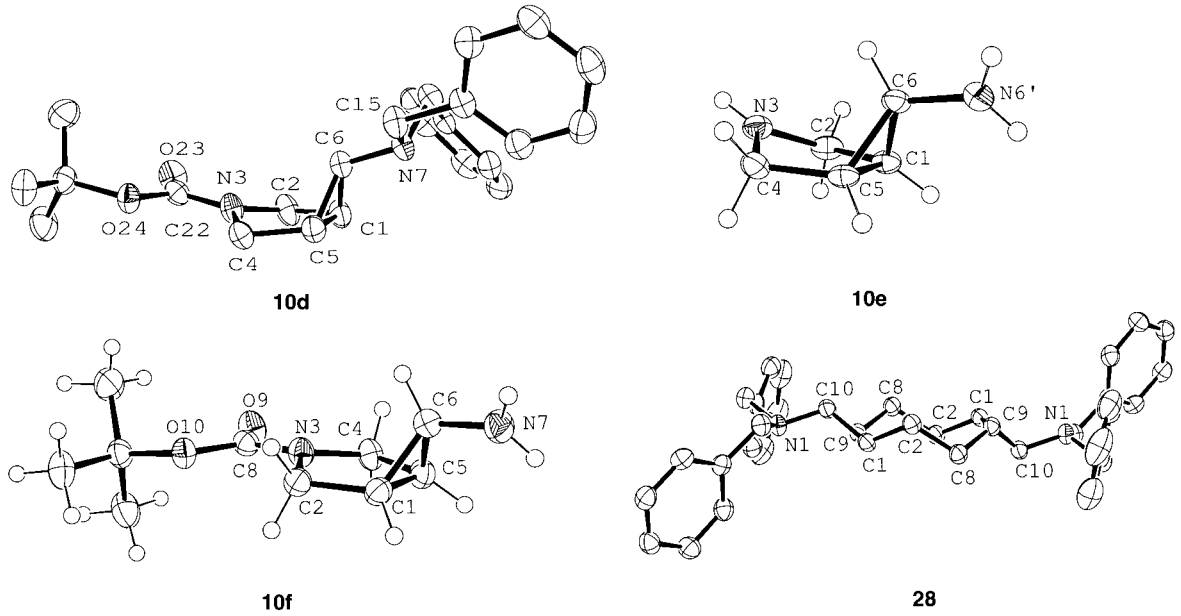


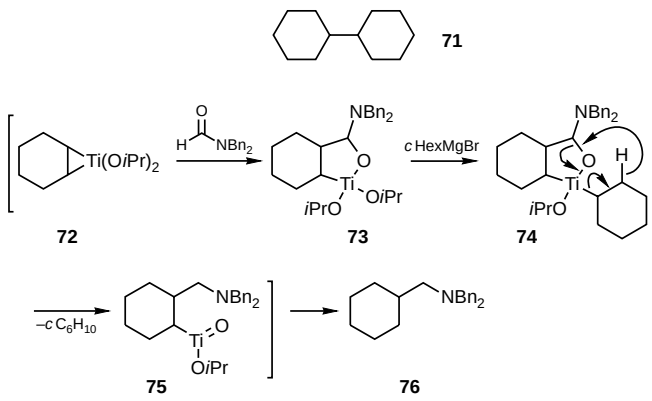
Figure 1. Structures of 3-*tert*-butoxycarbonyl-6-*exo*-(*N,N*-dibenzylamino-3-azabicyclo[3.1.0]hexane (**10d**), 6-*exo*-amino-3-azabicyclo[3.1.0]hexane (**10e**), 6-*exo*-amino-3-*tert*-butoxycarbonyl-3-azabicyclo[3.1.0]hexane (**10f**), and *exo,exo*-5,10-bis(dibenzylamino)-*anti*-tricyclo[7.1.0.0^{4,6}]decane (**28**) in the crystals.[20]

(4.31 Å), and it is slightly shorter in **10d** and **10e** (4.22 and 4.28 Å, respectively).

The tricyclic skeleton of **28**, in the crystal, adopts an ideal crown shape with the central eight-membered ring in a chair conformation[28] (Figure 1). As is usual in cyclopropylamines,[29] and in donor-substituted cyclopropane derivatives in general,[30] the distal bond (with respect to the amino substituent) is longer than the proximal bonds in all four molecules (1.517(2) vs. 1.498(2) (av) in **10d**; 1.511(4) vs. 1.508(2) in **10e**; 1.512(3) vs. 1.502(3) in **10f**; 1.522(2) vs. 1.510(2) in **28**).

In all cases, in which no or only low yields of cyclopropylamines were produced, three by-products were observed in varying amounts. One of them was, naturally, *exo*-7-(*N,N*-dibenzylamino)bicyclo[4.1.0]heptane (**23**) resulting from non-ligand exchanged cyclopropanation with the 6-titanabicyclo[4.1.0]heptane intermediate originally formed from cyclohexylmagnesium bromide. The second and third went unidentified for some time, however, they were finally assigned as 1,1′-bicyclohexyl (**71**)[18] and dibenzyl(cyclohexylmethyl)-amine (**76**)[31] by comparison with authentic samples. In most cases these by-products could be removed from the crude reaction mixtures either by distillation or chromatography.

The major fraction of **71** resulted from a Wurtz type reaction in the preparation of the Grignard reagent, in which the yield of 1,1′-bicyclohexyl (**71**) amounted up to 60%, when THF was used as the solvent. However, it is yet unknown, how the tertiary amine **76** would be formed. It cannot arise from hydrolysis of the unreacted oxatitanacyclopentane intermediate **73** of type **7** formed from the titanabicyclo[4.1.0]heptane **72** (from cyclohexylmagnesium bromide and MeTi(O*i*Pr)$_3$) and *N,N*-dibenzylformamide. One possible rationalization is that **73** reacts with another molecule of cyclohexylmagnesium bromide to yield **74** in which a β-hydride is transferred to the O,N-acetal carbon atom (Scheme 5). The resulting intermediate **75**, upon hydrolysis, would yield **76**. This mechanism is unprecedented in the literature, if operable, however, it might also explain the formation of 3-isopropyl-*N*-benzylpyrrolidine **18** from *N*-benzylpyrroline **15** (see above).



Scheme 5.

Conclusion

In conclusion, the newly developed conditions constitute a significant advance towards a rather general synthesis of various substituted cyclopropylamines from cyclic and acyclic alkenes, alkadienes, and even trienes. Many of these virtually functionalized cyclopropylamines were previously difficult or even impossible to obtain. The bicyclic diamine **10**, especially in its mono-Boc-protected form **10f**, is an interesting template for the combinatorial synthesis of libraries of small molecules with a well-defined distance between two nitrogen atoms.[32]

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Experimental Section

^{1}H (250 MHz) and ^{13}C (62.9 MHz) NMR: Bruker AM 250, $CDCl_3$ as solvent, chemical shifts based on residual $CHCl_3$ relative to $SiMe_4$, coupling constants are reported in Hz. Mass spectra (MS): Varian MAT CH7, MAT 731, and high-resolution mass spectra (HRMS): Varian MAT 311A. The molecular compositions were determined by high-resolution mass spectrometry with preselected ion peak matching at $R \gg 10000$ to be within ± 2 ppm of the exact masses. Melting points were determined on a Büchi 510 melting point apparatus and are uncorrected. Microanalyses were performed by the Mikroanalytisches Laboratorium des Instituts für Organische Chemie der Georg-August-Universität Göttingen. Experiments were conducted either under an atmosphere of nitrogen or argon and tetrahydrofuran (THF) was freshly distilled from sodium/benzophenone. All cyclic alkenes, dienes and trienes were commercially available from either Sigma-Aldrich, Merck-Schuchardt or Fluka companies. These alkenes were further purified by distillation under reduced pressure or distillation from calcium hydride under an atmosphere of argon and then stored at $-24\,^\circ$C. Grignard reagents were also purchased from the above companies except for cyclohexylmagnesium bromide,[33] molar concentrations were determined by acid/base titration against phenolphthalein. Radial chromatography was performed on a Chromatotron, Model 7924T using silica gel PF-254 with $CaSO_4 \cdot 1/2\,H_2O$ type 60 for TLC, E. Merck, Darmstadt. Column chromatography was performed on flash silica gel 60 mesh or alumina B, ICN. ^{13}C and ^{1}H NMR spectra only of major diastereomers are reported, unless stated otherwise, because of too many overlapping indistinguishable peaks in the spectra of diastereomeric mixtures.

General procedure A for the aminocyclopropanation of alkenes (GP A): Methylmagnesium chloride (1.79 mL, 3 M solution in THF) was added dropwise over 5–10 min at 0–5 °C to a solution of titanium tetraisopropoxide (1.43 mL, 4.88 mmol) in anhydrous THF (15 mL). After the mixture had been stirred for a further 5 min, a solution of *N,N*-dibenzylformamide (1.00 g, 4.44 mmol) in anhydrous THF (6 mL) was added over 30 s followed by addition of the respective alkene (4.88 mmol). Cyclohexylmagnesium bromide (2.69 mL, 2.0 M solution in diethyl ether) was then added dropwise over 45–50 min. The reaction mixture was allowed to warm to room temperature over 9-–26 h before it was quenched with water (2.5 mL) (exothermic reaction). After the resulting precipitate became white in color (ca. 15 min) it was removed by vacuum filtration. The precipitate was washed with diethyl ether (20 mL) and the combined filtrates were concentrated. The residue was purified affording pure product. Yields given below are based on *N,N*-dibenzylformamide used.

General procedure B for the aminocyclopropanation of alkenes (GP B): Titanium tetraisopropoxide (1 equiv) was added over 5 min at room temperature to a solution of equivalent amounts of alkene or diene (13.3–39.6 mmol, 1 equiv) and *N,N*-dibenzylformamide (1 equiv) in anhydrous THF (40–60 mL). Cyclohexylmagnesium bromide (2.0–2.5 equivalents of a 2.1–2.2 M solution in diethyl ether) was added over 35–45 min at room temperature followed by further stirring for 12 h. The resultant black-brown suspension was quenched with water (3.0–5.0 mL) (exothermic reaction), and the mixture stirred until the precipitate became white in color. The precipitate was removed by vacuum filtration and was washed with deithyl ether (35–50 mL). The combined filtrate was dried ($MgSO_4$) and the solution concentrated under reduced pressure to give a residue which was purified providing pure product.

General procedure C for the aminocyclopropanation of alkenes (GP C): A solution of the corresponding cycloalkylmagnesium bromide (31.0 mmol) in THF/benzene (3:1) was added dropwise by syringe to a solution of *N,N*-dibenzylformamide (2.25 g, 10.0 mmol), titanium tetraisopropoxide (2.84 g, 10.0 mmol) and cycloalkene (10.0 mmol) in THF (10 mL) at room temperature over a period of 20 min. The mixture was then stirred under reflux for 10 min, quenched with water (15 mL), and diluted with petroleum ether (10 mL). The precipitate was removed by vacuum filtration and washed with petroleum ether (50 mL). The combined organic extracts were evaporated in vacuo and the residue was dissolved in diethyl ether (50 mL) and treated with 25% aqueous sulfuric acid (15 mL). The aqueous phase contained a white solid precipitate which was treated with 30% sodium hydroxide solution (10 mL) and extracted with diethyl ether (75 mL). The diethyl ether solution was dried (Na_2SO_4) and the solvent evaporated in vacuo affording the pure product.

General procedure D for the aminocyclopropanation of alkenes (GP D): Cyclohexylmagnesium bromide solution in diethyl ether (1.5–2.4 equiv) over 10 s–1 h was added to a solution of the corresponding alkene (1.0–1.2 equiv), *N,N*-dimethyl-, or *N,N*-dibenzylformamide (1 equiv) and methyltitanium triisopropoxyde (1.0–1.5 equiv) in THF at ambient temperature under an atmosphere of argon. After additional stirring the above work-up (see **GP A** or **B**) gave a residue that was subjected to column chromatography or Kugelrohr distillation.

General procedure E for the aminocyclopropanation of alkenes (GP E): A cold solution of *N*-arylmethylpyrroline **15b,c** (7.50 mmol), titanium tetraisopropoxide (7.55 mmol), and *N,N*-bis(arylmethyl)formamide (7.50 mmol) in THF (5–10 mL) was added in one portion to a cooled (0 °C) solution of cyclohexylmagnesium bromide, obtained by addition of cyclohexyl bromide (25.0 mmol) in THF (10 mL) to magnesium turnings (0.60 g, 25.0 mmol). The mixture was slowly warmed up to room temperature over a period of 30–45 min and then heated under reflux for 60–120 min. The resulting reaction mixture was quenched with a solution of saturated sodium sulfate (2 mL) and diluted with petroleum ether (20 mL). The colorless precipitate was removed by filtration and the solvent evaporated in vacuo. The residue was dissolved in ethyl acetate (20 mL) and treated with 25% H_2SO_4 (10 mL). The aqueous phase was separated, treated with 30% NaOH solution (4 mL), and extracted with petroleum ether (50 mL). The organic layer was dried (K_2CO_3) and evaporated to give the crude product **10b,c** which was distilled in a Kugelrohr or used without additional purification.

3-Benzyl-6-*exo*-(*N,N*-dibenzylamino)-3-azabicyclo[3.1.0]hexane (10a): According to GP A, the mixture of *N*-benzylpyrroline (**15a**) (1.49 g, 9.37 mmol) and [Ti(O*i*Pr)$_4$] (2.84 g, 10.0 mmol) in THF (5 mL) was treated with MeMgCl (3.4 mL, 3 M in THF, 10.2 mmol), then a solution of *N,N*-dibenzylformamide (2.25 g, 10.0 mmol) in THF (10 mL) was added in one portion. Cyclohexylmagnesium bromide (14.0 mL, 21.4 mmol, 1.53 M in THF/benzene 3:1) was added at ambient temperature over 50 min and the reaction mixture was heated under reflux for 15 min. After work-up the residue was filtered through a pad of silica gel; elution with petroleum ether/ethyl acetate (15:1). Distillation (170 °C/10^{-4} Torr) of the crude product in a Kugelrohr gave the product **10a** as a pale yellow oil (3.00 g, 87%). ^{1}H NMR ($CDCl_3$): $\delta = 1.27$ (s, 2H), 2.21 (s, 1H), 2.31 (d, $J = 8.7$ Hz, 2H), 2.88 (d, $J = 8.7$ Hz, 2H), 3.56 (s, 2H), 3.65 (s, 4H), 7.26–7.33 ppm (m, 15H); ^{13}C NMR ($CDCl_3$): $\delta = 25.6$, 45.0, 54.4, 58.8, 59.1, 126.7, 126.8, 127.9, 128.1, 128.4, 129.4, 138.9, 139.5 ppm; HRMS calcd for $C_{26}H_{28}N_2$ 368.2252, found 368.2252; MS (EI$^+$): *m/z* (%): 368 (12), 277 (50), 249 (44), 210 (5), 172 (6), 158 (54), 131 (10), 106 (2), 91 (100).

6-*exo*-(*N,N*-Dibenzylamino)-3-(*p*-methoxybenzyl)-3-azabicyclo[3.1.0]hexane (10b): A solution of *N*-(*p*-methoxybenzyl)pyrroline (**15b**) (0.73 g 3.85 mmol), [Ti(O*i*Pr)$_4$] (1.11 g, 3.90 mmol) and *N,N*-dibenzylformamide (0.88 g, 3.90 mmol) in THF (5 mL) was treated with cyclohexylmagnesium bromide (13.30 mmol in THF (5 mL)) according to GP E. Yield: 1.05 g (68%). ^{1}H NMR ($CDCl_3$): $\delta = 1.32$ (bs, 2H), 2.26 (bs, 1H), 2.33–2.36 (bd, $J = 8.5$ Hz, 2H), 2.92 (d, $J = 8.8$ Hz, 2H), 3.55 (s, 2H), 3.71 (s, 4H), 3.86 (s, 3H), 6.91–6.94 (m, 2H), 7.23–7.26 (m, 2H), 7.31–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 25.6$, 44.9, 54.3, 55.2, 58.4, 59.5, 113.4, 126.7, 127.9, 129.4, 129.6, 131.5, 138.9, 158.4 ppm; HRMS calcd for $C_{27}H_{30}N_2O$: 398.2358, found 398.2358; MS (EI$^+$): *m/z* (%): 398 (12), 91 (100).

3-Benzyl-6-*exo*-[*N*-benzyl-*N*-(*p*-methoxybenzyl)amino]-3-azabicyclo[3.1.0]hexane (10c): A solution of *N*-benzylpyrroline (**15a**) (1.20 g, 7.54 mmol), [Ti(O*i*Pr)$_4$] (2.13 g, 7.50 mmol) and *N*-benzyl-*N*-(*p*-methoxybenzyl)formamide (1.91 g, 7.48 mmol) in THF (10 mL) was treated with cyclohexylmagnesium bromide (25.0 mmol in THF (10 mL)) according to GP E. Yield: 2.01 g (67%). ^{1}H NMR ($CDCl_3$): $\delta = 1.29$ (bs, 2H), 2.21 (bs, 1H), 2.33–2.36 (bd, $J = 8.5$ Hz, 2H), 2.91 (d, $J = 8.8$ Hz, 2H), 3.59 (s, 2H), 3.63 (s, 2H), 3.67 (s, 2H), 3.84 (s, 3H), 6.88–6.93 (m, 2H), 7.22–7.40 ppm (m, 12H); ^{13}C NMR ($CDCl_3$): $\delta = 25.6$, 44.8, 54.4, 55.2, 58.0, 58.7, 59.1, 113.2, 126.7, 127.9, 128.1, 128.5, 129.4, 130.6, 130.9, 139.0, 139.5, 158.5 ppm; HRMS calcd for $C_{27}H_{30}N_2O$: 398.2358, found 398.2358; MS (EI$^+$): *m/z* (%): 398 (8), 121 (100), 91 (60).

3-*tert*-Butyloxycarbonyl-6-*exo*-(*N,N*-dibenzylamino)-3-azabicyclo[3.1.0]-hexane (10d): According to GP A, a mixture of *N*-Boc-pyrroline (**15d**) (4.37 g, 25.8 mmol) and [Ti(O*i*Pr)$_4$] (9.20 mL, 30.9 mmol) in THF (70 mL) was treated with MeMgCl (10.4 mL, 3 M solution in THF, 31.2 mmol), and then a solution of *N,N*-dibenzylformamide (6.98 g, 30.9 mmol) in THF

(25 mL) was added in one portion. *c*HexMgBr (23.5 mL, 51.7 mmol, 2.2 M in Et_2O) was added at ambient temperature over 3 h, and the reaction mixture was heated under reflux for 15 min. After work-up the crude compound **10d** (9.90 g) was purified by column chromatography on basic alumina with activity grade II; elution with pentane/diethyl ether (5:1). The product **10d** (8.75 g, 90%) was obtained as a colorless solid. M.p. 79°C. ^{1}H NMR (C_6D_6): $\delta = 1.02-1.14$ (bm, 2H), 1.39–1.43 (m, 1H), 1.52 (s, 9H), 3.05 (dd, $J = 4.4$, 10.6 Hz, 1H), 3.21 (dd, $J = 4.4$, 11.0 Hz, 1H), 3.38 (d, $J = 10.6$ Hz, 1H), 3.45 (s, 4H), 3.62 (d, $J = 11.0$ Hz, 1H), 7.10–7.35 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 25.3$, 25.9, 28.5, 47.6, 47.7, 47.9, 58.9, 79.2, 127.0, 128.1, 129.4, 138.5, 154.6 ppm; HRMS calcd for $C_{24}H_{30}N_2O_2$ 378.2307, found 378.2307; MS (EI$^+$): *m/z* (%): 378 (48), 287 (33), 231 (44), 225 (35), 187 (72), 134 (42), 91 (100); elemental analysis calcd (%) for $C_{24}H_{30}N_2O_2$ (378.5): C 76.16, H 7.99; found: C 76.22, H 7.91. X-ray crystal structure analysis: see below.[20]

Carried out on a larger scale, this procedure furnished, from *N*-Boc-pyrroline (**15d**) (101 g, 0.60 mol) and [Ti(O*i*Pr)$_4$] (187 g, 0.66 mol) in THF (1.8 L), MeMgCl (219 mL, 3 M solution in THF, 0.66 mol), *N,N*-dibenzylformamide (148 g, 0.66 mol) and *c*HexMgBr (811 mL, 1.62 M solution in Et_2O), **10d** in 76% yield (172.5 g).

***exo*-6-(*N,N*-Dibenzylamino)bicyclo[3.1.0]hexane (12)**: According to GP B, cyclopentene (**19**) (2.70 g, 39.6 mmol), *N,N*-dibenzylformamide (8.99 g, 39.9 mmol) in anhydrous THF (15 mL), and cyclohexylmagnesium bromide (41.5 mL, 87.2 mmol, 2.1 M solution in diethyl ether) gave a crude product that was subjected to vacuum distillation (50–90°C/0.05 Torr) to remove 1,1′-dicyclohexyl. The residue was then subjected to column chromatography (hexanes) on silica gel to provide *exo*-7-(*N,N*-dibenzylamino)bicyclo[4.1.0]heptane (**23**) (1.30 g; 11%) as colorless crystals (m.p. 50°C) and **12** (3.12 g; 28%) as a colorless oil.

***exo*-7-(*N,N*-dibenzylamino)bicyclo[4.1.0]heptane (23)**: ^{1}H NMR ($CDCl_3$): $\delta = 0.85$ (s, 2H), 1.10–1.35 (m, 4H), 1.45–1.60 (m, 3H), 1.70–1.90 (m, 2H), 3.70 (s, 4H), 7.25–7.45 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 19.8$, 21.8, 22.9, 48.6, 58.4, 126.8, 128.0, 129.5, 138.6 ppm; HRMS calcd for $C_{21}H_{25}N$ 291.1987, found 291.1986; MS (EI$^+$): *m/z* (%): 291 (6), 262 (2), 236 (1), 210 (1), 200 (100), 181 (1), 161 (9), 146 (10), 132 (2), 118 (6), 106 (34), 91 (78).

***exo*-6-(*N,N*-Dibenzylamino)bicyclo[3.1.0]hexane (12)**: ^{1}H NMR ($CDCl_3$): $\delta = 0.98-1.12$ (m, 1H), 1.20 (br s, 2H), 1.50–1.68 (m, 6H), 3.65 (s, 4H), 7.26–7.39 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 22.5$, 27.2, 27.4, 44.3, 58.4, 126.9, 128.0, 129.6, 138.5 ppm; HRMS calcd for $C_{20}H_{23}N$ 277.1830, found 277.1830; MS (EI$^+$): *m/z* (%): 277 (6), 249 (1), 234 (1), 210 (7), 186 (100), 167 (3), 158 (6), 131 (3), 118 (5), 106 (30), 91 (42); elemental analysis calcd (%) for $C_{20}H_{23}N$ (277.4): C 86.59, H 8.36; found: C 86.53, H 8.45.

***exo*-6-(*N,N*-Dibenzylamino)bicyclo[3.1.0]hexane (12)**: According to GP C, cyclopentene (**19**) (0.68 g, 10.0 mmol) and cyclopentylmagnesium bromide (23.0 mL, 1.35 M, 31 mmol) in THF/benzene (3:1) after work-up gave pure **12** as a colorless oil (2.44 g, 88%).

***exo*-3-(*N,N*-Dibenzylamino)tricyclo[3.2.1.0^{2,4}]octane (21)**: According to GP B, norbornene (**20**) (1.30 g, 13.8 mmol) and cyclohexylmagnesium bromide (15.7 mL, 34.5 mmol, 2.2 M solution in diethyl ether) gave, after column chromatography (hexanes) on silica gel, **21** as colorless crystals (1.80 g, 43%), m.p. 31–33°C. ^{1}H NMR ($CDCl_3$): $\delta = 0.58$ (d, $J = 10.2$ Hz, 1H), 0.70 (s, 2H), 0.93 (d, $J = 10.2$ Hz, 1H), 1.19 (m, 2H), 1.33 (m, 2H), 1.72 (s, 1H), 2.20 (s, 2H), 3.57 (s, 4H), 7.25–7.30 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 25.4$, 29.3, 29.4, 35.6, 39.1, 58.0, 126.7, 127.9, 129.5, 138.5 ppm; HRMS calcd for $C_{22}H_{25}N$ 303.1987, found 303.1986; MS (EI$^+$): *m/z* (%): 303 (6), 274 (4), 226 (6), 212 (36), 200 (5), 167 (1), 144 (3), 118 (1), 107 (3), 91 (100); elemental analysis calcd (%) for $C_{22}H_{25}N$ (303.5): C 87.08, H, 8.30; found: C 86.95, H 8.45.

***exo*-7-(*N,N*-Dibenzylamino)bicyclo[4.1.0]heptane (23)**: According to GP C, cyclohexene (**22**) (0.82 g, 10.0 mmol) and cyclohexylmagnesium bromide (20.0 mL, 1.5 M, 30.0 mmol in THF/benzene 3:1) gave a crude product (1.35 g) that was subjected to column chromatography (petroleum ether/ethyl acetate, 20:1) on silica gel to afford **23** (0.80 g; 27%) as a colorless oil, and dibenzyl(cyclohexylmethyl)amine (**76**) (0.53 g; 18%). Spectroscopic and analytical data as reported above.

***N,N*-Dibenzyl-9-*exo*-aminobicyclo[6.1.0]nonane (25)**: According to GP C, cyclooctene (**24**) (0.54 g, 4.9 mmol) and cyclooctylmagnesium bromide (18.5 mL, 0.825 M, 15.26 mmol) in THF/benzene 3:1 gave, without acid/base purification, a crude product (2.28 g) that was subjected to column chromatography (petroleum ether/ethyl acetate, 20:1) on silica gel, affording 1,1′-bicyclooctyl (0.63 g), starting *N,N*-dibenzylformamide (0.12 g), dibenzyl(cyclooctylmethyl)amine (0.27 g; 17%), and the title compound **25** (0.53 g; 33%) as a pale yellow oil. ^{1}H NMR ($CDCl_3$): $\delta = 0.58-0.63$ (m, 1H), 0.87–0.95 (m, 2H), 1.17–1.26 (m, 4H), 1.29–1.63 (m, 6H), 1.78–1.85 (m, 2H), 3.54 (s, 4H), 7.22–7.38 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 25.6$, 25.7, 26.1, 29.3, 48.4, 58.6, 126.7, 127.9, 129.4, 139.0 ppm.

***exo*-9-(*N,N*-Dibenzylamino)bicyclo[6.1.0]non-4-ene (27)**: According to GP A, 1,5-cyclooctadiene (**26**) (0.528 g, 4.88 mmol) after 22 h, gave a crude product which was passed through a plug of silica gel; elution with *tert*-butyl methyl ether/hexane (2:98) afforded two fractions. The first one, which contained unreacted starting material and side products, was discarded. The second fraction (0.50 g) contained a mixture of the title compound **27**, *exo*-7-(*N,N*-dibenzylamino)bicyclo[4.1.0]heptane (**23**), and cyclohexyl(*N,N*-dibenzylamino)methane (**72**). This fraction was placed on a column containing silver nitrate impregnated silica gel.[34] The column was eluted (ethyl acetate/*n*-hexane 1:4) in the dark until eluting impurities could not be detected by TLC (silver nitrate impregnated) analysis. The impregnated silica gel was then quickly dried in vacuo and transferred from the column to a conical flask to which was added aqueous ammonia (25%). The slurry was extracted with *n*-hexane (2×100 mL) to give the product **27** ($\approx$90% pure) which was further purified by careful radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98) followed by Kugelrohr distillation (150–170°C/0.01 Torr) to afford **27** as a colorless oil (0.15 g; 11%). ^{1}H NMR ($CDCl_3$): $\delta = 0.70-0.90$ (m, 2H), 1.18–1.39 (m, 3H), 1.80–2.01 (m, 4H), 2.09–2.28 (m, 2H), 3.63 (s, 4H), 5.52–5.60 (m, 2H), 7.12–7.47 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 26.6$, 26.8, 28.5, 51.3, 58.7, 126.7, 127.9, 129.4, 130.2, 139.1 ppm; HRMS calcd for $C_{23}H_{27}N$ 317.2143, found 317.2143; MS (EI$^+$): *m/z* (%): 317 (14), 288 (3), 262 (4), 240 (5), 236 (8), 226 (29), 210 (5), 172 (1), 158 (6), 132 (9), 106 (10), 91 (100).

***exo,exo*-5,10-Bis(*N,N*-dibenzylamino)-*anti*-tricyclo[7.1.0.0^{4,6}]decane (28)**: With one equivalent of 1,5-cyclooctadiene (**26**) (1.20 g, 11.1 mmol) according to GP B, except that two equivalents of dibenzylformamide (5.00 g, 22.2 mmol), [Ti(O*i*Pr)$_4$] (6.31 mL, 21.4 mmol) in THF (60 mL) and four equivalents of cyclohexylmagnesium bromide (27.6 mL, 1.77 M, 49 mmol) were used. After 23 h the above work-up gave a mixture of compounds **23**, **27**, **28**, and **72** in a molar ratio of 1.20:1.35:0.34:1.00 (according to ^{1}H NMR spectroscopy). Column chromatography on silica gel (hexane) gave the only pure fraction containing compound **28** (85 mg; 1.5% based on diene) as a crystalline solid. M.p. 154°C. ^{1}H NMR ($CDCl_3$): $\delta = 0.70$ (s, 8H), 1.30 (s, 2H), 1.90 (s, 4H), 3.60 (s, 8H), 7.20–7.40 ppm (m, 20H); ^{13}C NMR ($CDCl_3$): $\delta = 26.9$, 28.3, 51.1, 58.6, 126.7, 127.9, 129.4, 138.9 ppm; HRMS calcd for $C_{38}H_{42}N_2$ 526.3348, found 526.3347; MS (EI$^+$): *m/z* (%): 526 (5), 435 (100), 344 (2), 330 (3), 292 (13), 240 (6), 196 (7), 172 (4), 120 (5), 106 (23), 91 (97). X-ray crystal structure analysis: see below.[20]

1-(*N,N*-Dibenzylamino)-2-ethyl-3-methylcyclopropane (30): According to GP A, *cis*-3-pentene (**29**) (0.26 mL, 0.171 g, 2.44 mmol) after 26 h gave a crude product that was subjected to column chromatography (ethyl acetate/*n*-hexane, 5:95) on silver nitrate impregnated silica gel,[34] affording three fractions. The first fraction (54 mg) contained the title compound **30** as a mixture of two diastereomers, and the second fraction (107 mg) contained a third diastereomer of **30**, overall yield 161 mg (26%). The two minor diastereomers could not be further separated. Two minor diastereomers: ^{1}H NMR ($CDCl_3$): $\delta = 0.14-0.26$ (m, 1H), 0.39–0.49 (m, 1H), 0.91 (d, $J = 6.1$ Hz, 3H), 1.01 (t, $J = 7.4$ Hz, 3H), 1.36–1.53 (m, 1H), 1.56–1.71 (m, 2H), 3.46 (d, $J = 13.5$ Hz, 2H), 3.76 (d, $J = 13.5$ Hz, 2H), 7.24–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 14.6$, 17.8, 20.35, 20.42, 29.2, 49.8, 58.4, 126.7, 127.9, 129.4, 138.9 ppm; ^{1}H NMR ($CDCl_3$): $\delta = 0.21-0.32$ (m, 1H), 0.51–0.63 (m, 1H), 0.83 (t, $J = 7.3$ Hz, 3H), 1.15 (d, $J = 6.1$ Hz, 3H), 1.36–1.53 (m, 1H), 1.56–1.71 (m, 2H), 3.56 (d, $J = 13.7$ Hz, 2H), 3.69 (d, $J = 13.7$ Hz, 2H), 7.24–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 12.6$, 13.3, 20.0, 25.7, 29.1, 48.1, 58.2, 126.7, 127.9, 129.4, 138.5 ppm; HRMS calcd for $C_{20}H_{25}N$ 279.1986, found 279.1986; MS (EI$^+$): *m/z* (%): (mixture of two minor isomers) 279 (5), 264 (4), 250 (12), 224 (1), 188 (90), 181 (4), 146 (2), 132 (2), 118 (5), 106 (22), 91 (100); elemental analysis calcd (%) for $C_{20}H_{25}N$ (279.4): C 85.97, H 9.02; found: C 86.20, H 8.99. Major diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 0.26-0.33$ (m, 1H), 0.54–0.61 (m, 1H), 0.70–0.85 (m, 1H), 0.88 (t, $J = 7.2$ Hz, 3H), 0.91–1.11 (m, 1H), 1.14–1.40 (m, 3H), 1.63 (sept, $J = 3.3$ Hz, 1H), 3.69 (d, $J = 13.6$ Hz, 2H), 3.75 (d, $J = 13.6$ Hz, 2H), 7.26–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 14.0$, 14.4, 21.7, 22.2, 34.7, 43.7, 57.2, 126.7, 127.9, 129.4, 138.8 ppm; HRMS calcd

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for $C_{20}H_{25}N$ 279.1986, found 279.1986; MS (EI^+): *m/z* (%): 279 (2), 250 (1), 236 (2), 188 (39), 146 (1), 132 (2), 118 (5), 106 (10), 91 (100).

1-(*N,N*-Dibenzylamino)-2,3-diethylcyclopropane (32): According to GP A, *trans*-3-hexene (**31**) (0.411 g, 4.88 mmol) after 18 h gave a crude product which was passed through a plug of silica gel (*tert*-butyl methyl ether/*n*-hexane, 1:4), then subjected to column chromatography (ethyl acetate/*n*-hexane, 5:95/10:90 gradient) on silver nitrate impregnated silica gel.[34] The first fraction contained one diastereomer of the title compound **32** (88 mg, 7%), other following fractions contained mixtures of two other diastereomers and cyclohexyl(*N,N*-dibenzylamino)methane (**72**). A second silver nitrate impregnated silica gel column (ethyl acetate/*n*-hexane, 2:98/5:95 gradient) removed amine **72** from the mixture to give an impure minor diastereomer of **32** (6 mg; 0.5%) (only benzyl group signals could be seen in the ^1H NMR spectrum) and the second diastereomer (81 mg; 6%). First diastereomer: ^1H NMR ($CDCl_3$): $\delta = 0.22-0.39$ (m, 1H), 0.45–0.60 (m, 1H), 0.89 (t, $J = 6.9$ Hz, 3H), 0.92–1.04 (m, 1H), 1.07 (t, $J = 7.4$ Hz, 3H), 1.34–1.54 (m, 2H), 1.61–1.79 (m, 2H), 3.58 (d, $J = 13.7$ Hz, 2H), 3.78 (d, $J = 13.7$ Hz, 2H), 7.26–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 13.4$, 14.6, 20.3, 25.8, 28.2, 28.3, 48.7, 58.1, 126.6, 127.9, 129.4, 138.9 ppm. Second diastereomer: ^1H NMR ($CDCl_3$): $\delta = 0.68-0.79$ (bm, 1H), 0.87 (t, $J =$ 7.3 Hz, 6H), 1.06–1.39 (m, 5H), 1.55–1.70 (bm, 1H), 3.65 (bs, 3H), 3.75 (s, 1H), 7.23–7.44 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 14.2$, 20.3, 28.1, 50.4, 57.9, 58.1, 126.6, 126.8, 127.9, 128.2, 128.7, 129.2, 139.2 (m), 139.6 ppm; HRMS calcd for $C_{21}H_{27}N$ 293.2143, found 293.2143; MS (EI^+): *m/z* (%): 293 (5), 278 (1), 264 (22), 202 (70), 181 (3), 172 (2), 144 (1), 118 (3), 106 (9), 91 (100); elemental analysis calcd (%) for $C_{21}H_{27}N$ (293.5): C 85.95, H 9.27; found: C 86.21, H 9.53.

7-(*N,N*-Dibenzylamino)spiro(cyclopropane-1,4′-bicyclo[3.1.0]hex-2-ene) (35): According to GP A, spiro[2.4]heptadiene (**34**) (0.450 g, 4.88 mmol) after 20 h, gave a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98/10:90 gradient) on silica gel to afford one fraction which contained a mixture of products including the title compound **35** (< 1%). HRMS calcd for $C_{22}H_{23}N$ 301.1830, found 301.1830.

***exo*-7-(*N,N*-Dibenzylamino)bicyclo[4.1.0]hept-2-ene (37)**: According to GP B at 5–10 °C, 1,3-cyclohexadiene (**36**) (1.10 g, 13.7 mmol) gave a crude product which was passed through a plug of silica gel (hexanes). The resulting pale yellow oil was subjected to vacuum distillation (133–140 °C/0.05 Torr), affording the title compound **37** (2.30 g, 58%). ^1H NMR ($CDCl_3$): $\delta = 1.15-2.05$ (m, 7H), 3.75 (s, 4H), 5.45 (m, 1H), 5.95 (m, 1H), 7.30–7.50 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 17.4$, 20.2, 21.7, 23.9, 48.1, 58.4, 123.6, 126.8, 127.2, 128.0, 129.5, 138.6 ppm; HRMS calcd for $C_{21}H_{23}N$ 289.1830, found 289.1830; MS (EI^+): *m/z* (%): 289 (7), 246 (1), 210 (5), 200 (13), 181 (4), 144 (2), 118 (3), 91 (100); elemental analysis calcd (%) for $C_{21}H_{23}N$ (289.4): C 87.14, H 8.02; found: C 87.24, H 8.23.

1-(*N,N*-Dibenzylamino)-2-phenylcyclopropane (39a): According to GP A, styrene (**38a**) (0.49 mL, 4.88 mmol) after 17 h gave a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98/10:90 gradient) on silica gel. This afforded the *E* isomer as a colorless solid (697 mg; 50%). M.p. 44–46 °C. Major diastereomer: ^1H NMR ($CDCl_3$): $\delta = 0.87-1.12$ (m, 2H), 1.81–1.88 (m, 1H), 2.02–2.1 (m, 1H), 3.68 (d, $J = 13.5$ Hz, 2H), 3.81 (d, $J = 13.5$ Hz, 2H), 6.78–6.86 (m, 2H), 7.10–7.20 ppm (m, 13H); ^{13}C NMR ($CDCl_3$): $\delta = 17.6$, 26.4, 47.6, 58.4, 125.3, 125.7, 126.8, 127.9, 128.0, 129.3, 138.6, 142.0 ppm; HRMS calcd for $C_{23}H_{23}N$ 313.1830, found 313.1830; MS (EI^+): *m/z* (%): 313 (5), 225 (22), 222 (43), 210 (58), 200 (6), 181 (4), 162 (2), 148 (7), 117 (6), 106 (4), 91 (100); elemental analysis calcd (%) for $C_{23}H_{23}N$ (313.4): C 88.14, H 7.40; found: C 88.39, H 7.76. The *Z* isomer was isolated as a colorless oil (223 mg, 16%). Minor diastereomer: ^1H NMR ($CDCl_3$): $\delta = 0.87-0.97$ (m, 1H), 1.00–1.11 (m, 1H), 2.06–2.26 (m, 2H), 3.38 (d, $J = 13.4$ Hz, 2H), 3.64 (d, $J = 13.4$ Hz, 2H), 7.02–7.18 (m, 4H), 7.18–7.54 ppm (m, 11H); ^{13}C NMR ($CDCl_3$): $\delta =$ 13.5, 23.8, 43.7, 57.3, 125.4, 126.7, 127.5, 127.8, 128.4, 129.5, 138.2, 138.3 ppm; HRMS calcd for $C_{23}H_{23}N$ 313.1830, found 313.1830; MS (EI^+): *m/z* (%): 313 (1), 222 (12), 181 (2), 165 (1), 132 (4), 117 (6), 106 (5), 91 (100); elemental analysis calcd (%) for $C_{23}H_{23}N$ (313.4): C 88.14, H 7.40; found: C 88.28, H 7.35.

1-(*N,N*-Dibenzylamino)-2-(4-methoxyphenyl)cyclopropane (39b): According to GP A, 4-methoxystyrene (**38b**) (0.655 g, 4.88 mmol) after 12 h gave a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98) on silica gel, affording the *E* and *Z* isomers of **39b**. The major diastereomer was isolated as a colorless oil (371 mg; 25%). ^1H NMR ($CDCl_3$): $\delta = 0.72-0.83$ (m, 1H), 0.93–1.04 (m, 1H), 1.96–2.16 (m, 2H), 3.33 (d, $J = 13.4$ Hz, 2H), 3.58 (d, $J = 13.4$ Hz, 2H), 3.81 (s, 3H), 6.82–6.91 (m, 2H), 7.04–7.14 (m, 3H), 7.16–7.33 ppm (m, 9H); ^{13}C NMR ($CDCl_3$): $\delta = 13.4$, 23.0, 43.2, 55.3, 57.3, 113.0, 126.7, 127.8, 129.2, 129.5, 130.2, 138.4, 157.7 ppm; HRMS calcd for $C_{24}H_{25}NO$ 343.1936, found 343.1936; MS (EI^+): *m/z* (%): 343 (14), 252 (47), 222 (30), 197 (3), 161 (2), 147 (8), 121 (100), 117 (4), 106 (5), 91 (86). The minor diastereomer was isolated as a colorless solid, m.p. 68–70 °C (315 mg, 20%). ^1H NMR ($CDCl_3$): $\delta = 0.91-1.11$ (m, 2H), 1.8–1.9 (m, 1H), 1.98–2.17 (m, 1H), 3.72 (d, $J = 13.5$ Hz, 2H), 3.85 (d, $J = 13.5$ Hz, 2H), 3.82 (s, 3H), 6.73–6.85 (m, 4H), 7.27–7.43 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta =$ 17.0, 25.6, 47.2, 55.2, 58.4, 113.4, 126.76, 126.80, 128.0, 129.3, 134.0, 138.7, 157.5 ppm; HRMS calcd for $C_{24}H_{25}NO$ 343.1936, found 343.1936; MS (EI^+): *m/z* (%): 343 (17), 252 (46), 222 (32), 210 (7), 197 (3), 147 (9), 121 (94), 117 (5), 106 (4), 91 (100); elemental analysis calcd (%) for $C_{24}H_{25}NO$ (343.5): C 83.93, H 7.34; found: C 83.90, H 7.56.

2-(2-Bromophenyl)-1-(*N,N*-dibenzylamino)cyclopropane (39c): According to GP A (but adding *c*HexMgBr within 20 min), 2-bromostyrene (**38c**) (0.894 g, 4.88 mmol) after 20 h gave a crude product that was subjected to careful radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98) on silica gel, affording the title compound **39c** (533 mg) as a colorless oil with unidentified minor impurities (2%). The calculated yield of pure **39c** is 522 mg (30%). Major diastereomer: ^1H NMR ($CDCl_3$): $\delta =$ 0.91–1.02 (m, 1H), 1.09–1.21 (m, 1H), 2.13–2.23 (m, 1H), 2.36–2.48 (m, 1H), 3.71 (d, $J = 13.6$ Hz, 2H), 3.88 (d, $J = 13.6$ Hz, 2H), 6.75–6.83 (m, 1H), 6.98–7.08 (m, 1H), 7.15–7.45 (m, 11H), 7.51–7.58 ppm (m, 1H); ^{13}C NMR ($CDCl_3$): $\delta = 18.7$, 26.0, 47.0, 57.6, 125.5, 126.8, 126.9, 127.2, 128.1, 129.1, 129.4, 132.5, 138.2, 140.9 ppm; HRMS calcd for $C_{23}H_{22}BrN$ 391.0935, found 391.0935; MS (EI^+): *m/z* (%): 393/391 (4/4), 391 (4), 312 (1), 300 (39), 287 (5), 222 (13), 210 (6), 196 (4), 169 (10), 116 (8), 91 (100). The minor diastereomer (> 1%) was obtained as a mixture with other products which could not be further purified.

1-(*N,N*-Dibenzylamino)-2-(2-trifluoromethylphenyl)cyclopropane (41a): According to GP A, 2-trifluoromethylstyrene (**40a**) (0.420 g, 2.44 mmol) after 20 h gave after above work-up a residue that was subjected to column chromatography (ethyl acetate/*n*-hexane, 5:95) on silver nitrate impregnated silica gel[34] to afford the title compound **41a** as a mixture of diastereomers (4:1), which was further purified by Kugelrohr distillation (170 °C/0.01 Torr) to give a colorless oil (90 mg, 11%). ^1H NMR ($CDCl_3$): $\delta = 0.93-1.03$ (m, 1H), 1.18–1.26 (m, 1H), 2.27–2.49 (m, 2H), 3.68 (d, $J =$ 13.6 Hz, 2H), 3.82 (d, $J = 13.6$ Hz, 2H), 6.88 (d, $J = 7.8$ Hz, 1H), 7.14–7.45 (m, 12H), 7.62 ppm (d, $J = 7.9$ Hz, 1H); ^{13}C NMR ($CDCl_3$): $\delta = 20.8$, 22.2, 46.8, 57.3, 117.2, 124.7 (q, $J = 274.2$ Hz), 124.9, 125.1, 125.7 (q, $J = 23.0$ Hz), 126.9, 128.1, 129.4, 131.6, 138.0, 141.8 ppm (q, $J = 5.4$ Hz); HRMS calcd for $C_{24}H_{22}F_3N$ 381.1704, found 381.1704; MS (EI^+): *m/z* (%): 381 (9), 326 (1), 306 (32), 290 (100), 286 (12), 265 (6), 251 (7), 242 (7), 224 (16), 222 (14), 185 (5), 159 (16), 127 (23), 106 (9), 91 (88); elemental analysis calcd (%) for $C_{24}H_{22}F_3N$ (381.4): C 75.57, H 5.81; found: C 75.80, H 5.98.

1-(*N,N*-Dibenzylamino)-2-(4-trifluoromethylphenyl)cyclopropane (41b): According to GP A, 4-trifluoromethylstyrene (**40b**) (0.721 mL, 0.841 g, 4.88 mmol) gave after 10 h a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98) on silica gel, affording **41b** as a single diastereomer, as a colorless solid (300 mg; 18%). M.p. 54–56 °C. ^1H NMR ($CDCl_3$): $\delta = 0.96-1.07$ (m, 1H), 1.08–1.19 (m, 1H), 1.75–1.86 (m, 1H), 2.00–2.10 (m, 1H), 3.63 (d, $J = 13.4$ Hz, 2H), 3.85 (d, $J = 13.4$ Hz, 2H), 6.80 (d, $J = 8.1$ Hz, 2H), 7.24–7.39 (m, 10H), 7.44 ppm (d, $J = 8.1$ Hz, 2H); ^{13}C NMR ($CDCl_3$): $\delta = 17.8$, 26.6, 48.3, 58.8, 124.4 (q, $J = 270.7$ Hz), 124.8 (q, $J = 3.8$ Hz), 125.8, 127.0, 127.5 (q, $J = 32.1$ Hz), 128.1, 129.3, 138.6, 146.3 ppm; HRMS calcd for $C_{24}H_{22}F_3N$ 381.1704, found 381.1704; MS (EI^+): *m/z* (%): 381 (2), 362 (2), 290 (53), 222 (5), 200 (15), 185 (6), 159 (13), 131 (4), 118 (5), 106 (16), 91 (100); elemental analysis calcd (%) for $C_{24}H_{22}F_3N$ (381.4): C 75.57, H 5.81; found: C 75.40, H 5.82.

1-(*N,N*-Dibenzylamino)-2-(3-trifluoromethylphenyl)cyclopropane (41c): According to GP A, 3-trifluoromethylstyrene (**40c**) (0.420 g, 2.44 mmol) and *N,N*-dibenzylformamide (500 mg, 2.22 mmol) gave after 24 h a crude product that was subjected to column chromatography (ethyl acetate/*n*-hexane, 5:95) on silver nitrate impregnated silica gel,[34] affording **41c** as a mixture of diastereomers (11.5:1), as a colorless oil (390 mg; 46%). ^1H NMR ($CDCl_3$): $\delta = 1.06-1.23$ (m, 2H), 1.80–1.89 (m, 1H), 2.05–2.13 (m, 1H), 3.69 (d, $J = 13.3$ Hz, 2H), 3.96 (d, $J = 13.3$ Hz, 2H), 6.91–7.0 (m,

2H), 7.25–7.50 ppm (m, 12H); ^{13}C NMR ($CDCl_3$): $\delta = 17.0$, 26.7, 48.2, 59.0, 122.1 (q, $J = 15.2$ Hz), 122.7 (q, $J = 15.0$ Hz), 124.6 (q, $J = 226.4$ Hz), 127.0, 128.15, 128.24, 128.6, 129.3, 130.1 (m), 138.6, 143.0 ppm; HRMS calcd for $C_{24}H_{22}F_3N$ 381.1704, found 381.1704; MS (EI$^+$): *m/z* (%): 381 (5), 362 (1), 326 (1), 306 (58), 290 (67), 286 (18), 265 (7), 251 (7), 242 (10), 224 (26), 222 (11), 185 (3), 168 (6), 159 (20), 133 (12), 127 (41), 106 (3), 91 (100); elemental analysis calcd (%) for $C_{24}H_{22}F_3N$ (381.4): C 75.57, H 5.81; found: C 75.87, H 5.94.

1-(*N*,*N*-Dibenzylamino)-2-[3,5-bis(trifluoromethyl)phenyl]cyclopropane (41d): According to GP A, 3,5-bis(trifluoromethyl)styrene (**40d**) (1.173 g, 4.88 mmol) gave after 24 h a crude product that was subjected to column chromatography (ethyl acetate/*n*-hexane, 5:95) on silver nitrate impregnated silica gel[34] to afford **41d** as a mixture of diastereomers (16:1), which was further purified by Kugelrohr distillation (170 °C/0.01 Torr) to give a colorless oil (172 mg; 9%). ^{1}H NMR ($CDCl_3$): $\delta = 1.05$–1.27 (m, 2H), 1.69–1.80 (m, 1H), 1.96–2.41 (m, 1H), 3.58 (d, $J = 13.2$ Hz, 2H), 3.97 (d, $J = 13.2$ Hz, 2H), 6.98 (s, 2H), 7.10–7.50 (m, 10H), 7.66 ppm (s, 1H); ^{13}C NMR ($CDCl_3$): $\delta = 16.7$, 27.0, 48.9, 59.6, 119.1 (sextet, $J = 3.9$ Hz), 123.4 (q, $J = 272.6$ Hz), 125.6 (m), 127.2, 128.3, 129.3, 131.0 (q, $J = 32.8$ Hz), 138.9, 144.6 ppm; HRMS calcd for $C_{25}H_{21}F_6N$ 449.1578, found 449.1578; MS (EI$^+$): *m/z* (%): 449 (6), 430 (3), 358 (100), 287 (3), 253 (4), 224 (9), 222 (6), 196 (3), 160 (6), 130 (2), 118 (3), 91 (71).

1-(*N*,*N*-Dibenzylamino)-2-furanylcyclopropane (43): According to GP A, 2-ethenylfuran (**42**) (0.460 g, 4.89 mmol) gave after 24 h a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 5:95) on silica gel to afford a mixture (*cis*/*trans* = 1:4) of **43** (576 mg; 43%) and trace amounts of *exo*-7-(*N*,*N*-dibenzylamino)bicyclo[4.1.0]heptane (**23**) as a colorless oil. Minor diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 0.88$–0.94 (m, 1H), 1.01–1.10 (m, 1H), 2.01–2.10 (m, 1H), 2.13–2.20 (m, 1H), 3.40 (d, $J = 13.6$ Hz, 2H), 3.72 (d, $J = 13.6$ Hz, 2H), 6.01–6.12 (m, 1H), 6.37–6.40 (m, 1H), 7.09–7.45 ppm (m, 11H); ^{13}C NMR ($CDCl_3$): $\delta = 13.0$, 17.0, 42.7, 57.1, 106.3, 110.3, 126.7, 127.9, 129.4, 138.3, 140.8, 153.9 ppm. Major diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 0.95$–1.09 (m, 2H), 1.85–1.93 (m, 1H), 2.16–2.22 (m, 1H), 3.77 (dd, $J = 13.5$, 15.5 Hz, 4H), 5.80–5.82 (m, 1H), 6.28 (dd, $J = 1.9$, 3.2 Hz, 1H), 7.24–7.46 ppm (m, 11H); ^{13}C NMR ($CDCl_3$): $\delta = 15.7$, 19.4, 44.5, 58.0, 103.7, 110.2, 126.9, 128.0, 129.4, 138.3, 140.2, 155.5 ppm; HRMS calcd for $C_{21}H_{21}NO$ 303.1623, found 303.1623; MS (EI$^+$): *m/z* (%): (mixture) 303 (8), 287 (1), 224 (4), 222 (7), 212 (19), 210 (5), 181 (2), 146 (2), 132 (2), 117 (4), 106 (9), 91 (100).

1-(*N*,*N*-Dibenzylamino)-2-ethoxycyclopropane (45): According to GP A, ethenyl ethyl ether (**44**) (0.352 g, 4.88 mmol) gave after 9 h a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98/10:90 gradient) on silica gel to afford **45** (52 mg; 4%) as a colorless oil. ^{1}H NMR ($CDCl_3$): $\delta = 0.60$–0.70 (m, 1H), 0.77–0.85 (m, 1H), 1.08 (t, $J = 7.0$ Hz, 3H), 2.0–2.06 (m, 1H), 3.1–3.15 (m, 1H), 3.19–3.44 (m, 2H), 3.68 (s, 4H), 7.22–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 15.0$, 15.5, 43.2, 57.4, 60.9, 65.4, 126.8, 128.0, 129.2, 138.4 ppm; HRMS calcd for $C_{19}H_{23}NO$ 281.1779, found 281.1779; MS (EI$^+$): *m/z* (%): 281 (4), 252 (18), 225 (3), 210 (6), 190 (26), 181 (4), 146 (6), 132 (2), 91 (100).

1-(*N*,*N*-Dimethylamino)-2-(*N*,*N*-dibenzylaminomethyl)cyclopropane (47a): According to GP D, cyclohexylmagnesium bromide (12.0 mL, 16.80 mmol, 1.4 M solution in THF) was added over 10 s to a solution of *N*,*N*-dibenzylallylamine (**46**) (2.00 g, 8.43 mmol), *N*,*N*-dimethylformamide (0.616 g, 8.43 mmol), and [MeTi(O*i*Pr)$_3$] (3.04 g, 12.65 mmol) in anhydrous THF (20 mL) at ambient temperature under an atmosphere of argon. After 5 h the above mentioned work-up gave a crude product that was subjected to column chromatography (diethyl ether/petroleum ether/triethylamine, 1:1:0/49:49:2 gradient) on silica gel to afford a mixture (1:5) of two diastereomers (1.09 g; 44%). Minor diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 0.24$ (m, 1H), 0.74 (m, 1H), 0.98 (m, 1H), 1.55 (m, 1H), 2.24 (s, 6H), 2.40 (dd, $J = 8.1$, 13.0 Hz, 1H), 3.00 (dd, $J = 4.4$, 13.0 Hz, 1H), 3.54 (d, $J = 13.8$ Hz, 2H), 3.82 (d, $J = 13.8$ Hz, 2H), 7.20–7.45 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 12.6$, 16.7, 43.6, 45.9, 52.6, 58.2, 126.6, 128.0, 128.8, 140.0 ppm. Major diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 0.28$ (m, 1H), 0.62 (m, 1H), 1.11 (m, 1H), 1.31 (m, 1H) 2.22 (dd, $J = 7.4$, 13.3 Hz, 1H), 2.33–2.42 (m, 7H), 3.61 (d, $J = 13.7$ Hz, 2H), 3.69 (d, $J = 13.7$ Hz, 2H), 7.20–7.45 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 13.0$, 18.4, 45.2, 46.4, 55.9, 58.1, 126.7, 128.2, 128.6, 139.9 ppm; MS (EI$^+$): *m/z* (%): 294 (3), 250 (20), 210 (100), 91 (90); elemental analysis calcd (%) for $C_{20}H_{26}N_2$ (294.4): C 81.59, H 8.90; found: C 81.35, H 8.78.

1-(*N*,*N*-Dibenzylamino)-2-(*N*,*N*-dibenzylaminomethyl)cyclopropane (47b): According to GP D, *N*,*N*-dibenzylformamide (2.00 g, 8.88 mmol), *N*,*N*-dibenzylallyamine (**46**) (2.32 g, 9.78 mmol), [MeTi(O*i*Pr)$_3$] (2.56 g, 10.7 mmol) in anhydrous THF (40 mL), and cyclohexylmagnesium bromide (12.2 mL, 17.8 mmol, 1.46 M solution in diethyl ether, addition within 1–2 min) gave the crude product **47b** which was further purified by column chromatography on deactivated (NEt_3) silica gel (petroleum ether/diethyl ether, PE/DE 10:1) to yield a mixture (1:4, according to ^{1}H NMR spectroscopy) of two diastereomers (1.53 g; 39%). Minor diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 0.24$ (m, 1H), 0.71 (m, 1H), 1.04 (m, 1H), 1.92 (m, 1H), 2.48–2.64 (m, 2H), 3.40–3.80 (m, 8H); 7.00–7.50 ppm (m, 20H); ^{13}C NMR ($CDCl_3$): $\delta = 12.8$, 17.1, 41.1, 51.5, 58.0, 58.5, 126.6, 127.9, 128.1, 128.7, 128.9, 129.3, 138.4, 140.1 ppm. Major diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 0.32$ (m, 1H), 0.63 (m, 1H), 0.97 (m, 1H), 1.58 (m, 1H), 2.03 (dd, $J = 13.2$, 7.9 Hz, 1H), 2.42 (dd, $J = 13.2$, 5.5 Hz, 1H), 3.51 (d, $J = 13.7$ Hz, 2H), 3.59 (d, $J = 13.7$ Hz, 2H), 3.65 (d, $J = 13.5$ Hz, 2H), 3.73 (d, $J = 13.5$ Hz, 2H), 7.10–7.50 ppm (m, 20H); ^{13}C NMR ($CDCl_3$): $\delta = 14.5$, 19.3, 42.4, 55.8, 57.9, 58.4, 126.7, 126.8, 128.0, 128.1, 128.6, 129.3, 138.8, 139.9 ppm. Diastereomeric mixture: MS (EI$^+$): *m/z* (%): 446 (< 1), 355 (8), 249 (20), 236 (20), 210 (80), 91 (100); elemental analysis calcd (%) for $C_{32}H_{34}N_2$ (446.4): C 86.05, H 7.67; found: C 85.87, H 7.91.

***trans*-1-(*N*,*N*-Dibenzylamino)-2-trimethylsilylcyclopropane (49)**: According to GP D, *N*,*N*-dibenzylformamide (2.00 g, 8.88 mmol), ethenyltrimethylsilane (**48**) (1.07 g, 10.66 mmol), [MeTi(O*i*Pr)$_3$] (2.56 g, 10.65 mmol) in anhydrous THF (20 mL), and cyclohexylmagnesium bromide (17.0 mL, 22.6 mmol, 1.33 M solution in diethyl ether, addition over 1 h) gave the crude product **49** which was purified from side products [1,1′-bicyclohexyl (**71**)] by distillation in a Kugelrohr at 100 °C/0.01 Torr. The pure **49** was obtained by repeated distillation at 150–175 °C/0.01 Torr (colorless oil, 1.62 g; 59%) as the single *trans* isomer according to H,H NOESY. ^{1}H NMR ($CDCl_3$): $\delta = -0.24$ to -0.14 (m, 1H), -0.07 (s, 9H), 0.34–0.41 (m, 1H), 0.56–0.63 (m, 1H), 1.79–1.84 (m, 1H), 3.64 (d, $J = 13.6$ Hz, 2H), 3.76 (d, $J = 13.6$ Hz, 2H), 7.23–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = -2.2$, 7.5, 11.8, 41.0, 58.7, 126.7, 128.0, 128.1, 139.1 ppm; HRMS calcd for $C_{20}H_{27}NSi$: 309.1912, found 309.1912; MS: *m/z* (%): 309 (30), 294 (5), 236 (75), 218 (15), 91 (100), 73 (20); elemental analysis calcd (%) for $C_{20}H_{27}NSi$ (309.5): C 77.61, H 8.79; found: C 77.59, H 9.02.

1-(*N*,*N*-Dibenzylamino)-2-trimethylsilylmethylcyclopropane (51): According to GP D, *N*,*N*-dibenzylformamide (2.00 g, 8.88 mmol), allyltrimethylsilane (**50**) (1.217 g, 10.65 mmol), [MeTi(O*i*Pr)$_3$] (2.133 g, 8.88 mmol) in anhydrous THF (20 mL) and cyclohexylmagnesium bromide (9.1 mL, 13.3 mmol, 1.46 M solution in diethyl ether, addition within 1–2 min) gave the crude product **51** which was further purified by column chromatography on silica gel (PE/DE 10:1, $R_f = 0.60$) to yield one single diastereomer (0.805 g; 28%). ^{1}H NMR ($CDCl_3$): $\delta = -0.10$–0.10 (br s, 10H), 0.19 (m, 1H), 0.54 (m, 2H), 0.73 (m, 1H), 1.50 (m, 1H), 3.60 (d, $J = 13.3$ Hz, 2H), 3.75 (d, $J = 13.3$ Hz, 2H), 7.20–7.50 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = -1.5$, 16.0, 17.4, 20.1, 45.2, 58.6, 126.7, 127.9, 129.4, 139.0 ppm; HRMS calcd for $C_{21}H_{29}NSi$ 323.2069, found 323.2069; MS (EI$^+$): *m/z* (%): 323 (8), 308 (5), 250 (15), 232 (70), 91 (100), 73 (42); elemental analysis calcd (%) for $C_{21}H_{29}NSi$ (323.6): C 77.79, H 8.92; found: C 77.88, H 9.02..

1-(*N*,*N*-Dibenzylamino)-2-ethenylcyclopropane (53): According to GP D, cooled solutions (0 °C) of [MeTi(O*i*Pr)$_3$] (16.10 g, 67.0 mmol) in THF (20 mL) and *N*,*N*-dibenzylformamide (15.1 g, 67.0 mmol) in THF (20 mL) were added to a solution of butadiene (9.10 g, 168.2 mmol) in anhydrous THF (150 mL) at −40 °C under nitrogen. Cyclohexylmagnesium bromide (46 mL, 80.5 mmol, 1.75 M in diethyl ether) was added at −20 °C within 5 min. After 1 h at −20 to −10 °C and stirring at ambient temperature for 12 h, the reaction was quenched with water (50 mL) and worked up as above. Column chromatography (hexanes) on silica gel gave the title compound **53** (9.90 g; 56%). ^{1}H NMR ($CDCl_3$): $\delta = 0.81$ (m, 1H), 0.96 (m, 1H), 1.50 (m, 1H), 1.99 (m, 1H), 3.80 (d, $J = 14.0$ Hz, 2H), 3.91 (d, $J = 14.0$ Hz, 2H), 5.01 (dd, $J = 1.7$, 17.7 Hz, 1H), 5.03 (dd, $J = 1.7$, 9.6 Hz, 1H), 5.46–5.60 (m, 1H), 7.25–7.50 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 16.0$, 25.5, 45.3, 58.4, 112.3, 126.9, 128.1, 129.5, 138.7, 139.8 ppm; HRMS calcd for $C_{19}H_{21}N$ 263.1673, found 263.1673; MS (EI$^+$): *m/z* (%): 263 (9), 234 (5), 172 (48), 91 (100); elemental analysis calcd (%) for $C_{19}H_{21}N$ (263.4): C 86.65, H 8.04; found: C 86.79, H 8.11.

1-(*N*,*N*-Dibenzylamino)-2-ethenyl-2-methylcyclopropane (55): According to GP A, isoprene (**54**) (0.333 g, 4.89 mmol) gave after 15 h a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-

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hexane, 2:98/10:90 gradient) on silica gel to afford the title compound **55** as a colorless oil (730 mg; 59%). ^{1}H NMR ($CDCl_3$): $\delta = 0.51$ (t, $J = 4.8$ Hz, 1H), 0.81 (dd, $J = 4.8$, 7.4 Hz, 1H), 1.24 (s, 3H), 1.90 (dd, $J = 4.8$, 7.4 Hz, 1H), 3.60 (d, $J = 13.6$ Hz, 2H), 3.66 (d, $J = 13.6$ Hz, 2H), 4.87 (s, 1H), 4.92 (d, $J = 10.4$ Hz, 1H), 5.45 (dd, $J = 10.4$, 17.3 Hz, 1H), 7.25–7.38 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 15.2$, 21.5, 26.0, 49.9, 57.8, 109.7, 126.8, 128.0, 129.5, 138.3, 145.6 ppm; HRMS calcd for $C_{20}H_{23}N$ 277.1830, found 277.1830; MS (EI$^+$): *m/z* (%): 277 (10), 262 (3), 249 (5), 224 (11), 222 (7), 200 (3), 186 (31), 159 (1), 132 (4), 117 (3), 106 (7), 91 (100); elemental analysis calcd (%) for $C_{20}H_{23}N$ (277.4): C 86.59, H 8.36; found: C 86.37, H 8.18.

1-(*N,N*-Dibenzylamino)-2-ethenyl-3,3-dimethylcyclopropane (58): According to GP A, 4-methyl-1,3-pentadiene (**57**) (0.401 g, 4.88 mmol) gave after 10 h a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98/10:90 gradient) on silica gel to afford **58** as a colorless oil (824 mg; 64%), 1:5.3 mixture of diastereomers according to ^{1}H NMR. Major diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 0.99$ (s, 3H), 1.09 (s, 3H), 1.14 (dd, $J = 4.0$, 9.3 Hz, 1H), 1.70 (d, $J = 4.0$ Hz, 1H), 3.60 (s, 4H), 4.90 (m, 1H), 4.95 (s, 1H), 5.49 (m, 1H), 7.22–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 20.7$, 21.0, 26.5, 35.9, 56.0, 57.9, 114.1, 126.8, 128.0, 129.5, 137.5, 138.3 ppm. Minor diastereomer: ^{1}H NMR ($CDCl_3$): $\delta = 1.07$ (s, 6H), 1.39 (dd, $J = 7.3$, 10.01 Hz, 1H), 1.85 (d, $J = 7.3$ Hz, 1H), 3.50 (d, $J = 13.9$ Hz, 2H), 3.68 (d, $J = 13.9$ Hz, 2H), 5.02 (dd, $J = 2.2$, 10.3 Hz, 1H), 5.15 (dd, $J = 2.2$, 17.2 Hz, 1H), 5.91 (dt, $J = 10.3$, 17.2 Hz, 1H), 7.22–7.41 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 15.1$, 24.3, 27.0, 33.5, 52.1, 56.3, 114.7, 126.8, 128.0, 129.6, 135.8, 137.7 ppm; HRMS calcd for $C_{21}H_{25}N$ 291.1986, found 291.1986; MS (EI$^+$) (mixture of diastereomers): *m/z* (%): 291 (18), 276 (34), 248 (4), 234 (3), 224 (9), 222 (6), 200 (18), 181 (3), 174 (14), 158 (2), 146 (10), 132 (6), 117 (5), 106 (2), 91 (100); elemental analysis calcd (%) for $C_{21}H_{25}N$ (291.4): C 86.55, H 8.65; found: C 86.78, H 8.49.

1-(*N,N*-Dibenzylamino)-2-ethenyl-2-(4-methylpent-3-en-1-yl)cyclopropane (62): According to GP A, 0.923 mL of 90% myrcene (**61**) (0.665 g of pure **61**, 4.88 mmol) gave after 16 h a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 2:98/10:90 gradient) on silica gel to afford **62** as a colorless oil (783 mg, 51%). ^{1}H NMR ($CDCl_3$): $\delta = 0.49$ (t, $J = 5.0$ Hz, 1H), 0.91 (bt, $J = 5.0$ Hz, 1H), 1.62 (s, 3H), 1.73 (s, 3H), 1.81 (dd, $J = 5.0$, 7.2 Hz, 1H), 1.85–2.05 (m, 2H), 2.05–2.29 (m, 2H), 3.59 (d, $J = 13.8$ Hz, 2H), 3.66 (d, $J = 13.8$ Hz, 2H), 4.84 (dd, $J = 1.3$, 17.3 Hz, 1H), 4.91 (dd, $J = 1.3$, 10.6 Hz, 1H), 5.17 (m, 1H), 5.65 (dd, $J = 10.6$, 17.3 Hz, 1H), 7.25–7.35 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 17.7$, 19.2, 25.7, 26.7, 29.8, 30.8, 50.9, 57.6, 110.8, 125.0, 126.8, 128.0, 129.5, 131.1, 138.2, 143.5 ppm; HRMS calcd for $C_{25}H_{31}N$ 345.2457, found 345.2456; MS (EI$^+$): *m/z* (%): 345 (17), 316 (1), 287 (2), 276 (38), 254 (6), 239 (2), 224 (21), 210 (12), 200 (7), 181 (6), 174 (1), 146 (7), 106 (6), 91 (100); elemental analysis calcd (%) for $C_{25}H_{31}N$ (345.5): C 86.90, H 9.04; found: C 87.10, H 9.18.

***trans*-1-(*N,N*-Dibenzylamino)-2-phenyl-3-(2-phenylethenyl)cyclopropane (64)**: According to GP A, 1,4-diphenylbutadiene (**63**) (2.014 g, 9.76 mmol) gave after 20 h a crude product that was passed through a plug of silica gel (*tert*-butyl methyl ether/*n*-hexane, 3:7) to afford a mixture of **64** and *exo*-7-(*N,N*-dibenzylamino)bicyclo[4.1.0]heptane (**23**). The mixture was subjected to Kugelrohr distillation (110–120 °C/0.01 Torr) which removed **23** to leave a residue which was washed with small amounts of cold *n*-hexane to afford **64** (327 mg, 9%) as a colorless solid, which was recrystallized from *n*-hexane, m.p. 88–89 °C. (Note: Prolonged heating of the title compound **64** was found to partially isomerize the double bond). ^{1}H NMR ($CDCl_3$): $\delta = 2.09$ (dt, $J = 3.7$, 9.7 Hz, 1H), 2.55–2.65 (m, 2H), 3.84 (d, $J = 13.5$ Hz, 2H), 4.01 (d, $J = 13.5$ Hz, 2H), 5.69 (dd, $J = 9.7$, 15.8 Hz, 1H), 6.29 (d, $J = 15.7$ Hz, 1H), 7.23–7.48 ppm (m, 20H); ^{13}C NMR ($CDCl_3$): $\delta = 33.3$, 33.8, 50.4, 58.1, 125.6, 126.0, 126.6, 126.9, 127.7, 128.1, 128.3, 128.8, 129.3, 129.4, 130.2, 137.6, 137.8, 138.4 ppm; HRMS calcd for $C_{31}H_{29}N$ 415.2299, found 415.2299; MS (EI$^+$) *m/z* (%): 415 (35), 338 (3), 324 (20), 310 (9), 298 (7), 246 (2), 233 (5), 219 (6), 193 (12), 167 (2), 156 (4), 129 (5), 117 (18), 91 (100).

1-(*N,N*-Dibenzylamino)-2-ethenyl-3-(2-methylpropenyl)cyclopropane (66): According to GP A, 6-methyl-1,3,5-heptatriene (**65**) (0.528 g, 4.88 mmol) gave after 26 h a crude product that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 8:92) on silica gel, affording a mixture of the title compound **66** (758 mg, 54%) (ratio of diastereomers 1:1.5:1.5 according ^{1}H NMR) and trace amounts of *exo*-7-(*N,N*-dibenzylamino)bicyclo[4.1.0]heptane (**23**) as a colorless oil. Two major diastereomers: ^{1}H NMR ($CDCl_3$): $\delta = 1.29–1.36$ (m, 1H), 1.47 (s, 3H), 1.49–1.62 (m, 3H), 1.69 (s, 3H), 1.73 (s, 3H), 1.78 (s, 3H), 2.05–2.11 (m, 2H), 3.48 (d, $J = 13.5$ Hz, 2H), 3.50 (d, $J = 13.7$ Hz, 2H), 3.78 (d, $J = 13.7$ Hz, 2H), 3.81 (d, $J = 13.5$ Hz, 2H), 4.62 (bd, $J = 9.3$ Hz, 1H), 4.80 (m, 2H), 5.01–5.23 (m, 2H), 5.30 (bd $J = 9.3$ Hz, 1H), 5.37–5.52 (m, 1H), 5.93–6.08 (m, 1H), 7.25–7.48 ppm (m, 20H); ^{13}C NMR ($CDCl_3$): $\delta = 18.1$, 18.2, 25.5, 25.8, 27.5, 29.3, 32.6, 33.1, 50.1, 50.5, 57.2, 57.3, 112.3, 113.6, 122.3, 124.7, 126.8, 127.97, 128.00, 129.4, 129.5, 131.7, 131.9, 137.2, 138.2, 138.3, 139.1 ppm. Minor, mixture of three: ^{1}H NMR ($CDCl_3$): $\delta = 1.28–1.35$ (m, 1H), 1.49–1.62 (m, 1H), 1.55 (s, 3H), 1.71 (s, 3H), 1.91–1.94 (m, 1H), 3.71 (s, 4H), 4.98 (d, $J = 16.2$ Hz, 1H), 5.01–5.23 (m, 2H), 5.93–6.07 (m, 1H), 7.26–7.42 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 18.2$, 25.7, 28.4, 32.6, 51.9, 57.8, 114.5, 121.2, 126.8, 128.0, 129.4, 133.3, 136.5, 138.1 ppm; HRMS calcd for $C_{23}H_{27}N$ 317.2143, found 317.2143; MS (EI$^+$) (mixture): *m/z* (%):317 (20), 302 (7), 274 (2), 248 (4), 226 (9), 222 (5), 184 (2), 177 (5), 158 (6), 132 (9), 106 (5), 91 (100).

Debenzylation of 3-benzyl-6-*exo*-(*N,N*-dibenzylamino)-3-azabicyclo[3.1.0]hexane (10a): 6-*exo*-amino-3-azabicyclo[3.1.0]hexane (10e): 10% Pd/C (1.06 g, 10 mol%) was added to a stirred solution of 3-benzyl-6-*exo*-(dibenzylamino)-3-azabicyclo[3.1.0]hexane (**10a**) (3.70 g, 10.05 mmol) in methanol (40 mL). Hydrogen was passed through the suspension for 12 h. The catalyst was removed by using a celite pad, which was then washed with methanol (50 mL). The combined filtrates were evaporated at reduced pressure, the residue dissolved in diethyl ether (50 mL), and dried (KOH). The diethyl ether was removed in vacuo and the residue subjected to Kugelrohr distillation (110 °C/6 Torr), affording *exo*-6-amino-3-azabicyclo[3.1.0]hexane (**10e**) (0.92 g; 93%) as colorless crystals. M.p. 50 °C. ^{1}H NMR ($CDCl_3$): $\delta = 1.17–1.19$ (bdd, $J = 2.1$, 3.2, 2H), 1.58 (s, 3H), 1.90–1.91 (bt, $J = 2.1$, 1H), 2.67–2.72 (m, 2H), 2.84 ppm (d, $J = 11.3$, 2H); ^{13}C NMR ($CDCl_3$): $\delta = 26.6$, 31.4, 47.8 ppm; MS (CI$^+$): *m/z* (%): 197 (100), 116 (84). X-ray crystal structure analysis: see below.[20]

Debenzylation of 3-benzyl-6-*exo*-(*N,N*-dibenzylamino)-3-azabicyclo[3.1.0]hexane (10a) in the presence of acetic acid: 6-*exo*-amino-3-azabicyclo[3.1.0]hexane (10e): Acetic acid (1.5 mL) was added to a stirred solution of 3-benzyl-6-*exo*-(dibenzylamino)-3-azabicyclo[3.1.0]hexane (**10a**) (4.85 g, 13.16 mmol) in methanol (80 mL). After 10 min 10% Pd/C (234 mg, 1.7 mol%) was added. Hydrogen was then passed through the suspension for 20 h. The catalyst was removed by using a celite pad, which was then washed with methanol (50 mL). The combined filtrates were evaporated at reduced pressure, the residue dissolved in diethyl ether (50 mL) and dried with KOH. The diethyl ether was removed in vacuo and the residue subjected to Kugelrohr distillation (110 °C/6 Torr), affording *exo*-6-amino-3-azabicyclo[3.1.0]hexane (**10e**) (1.20 g; 93%) as a colorless solid.

Debenzylation of 3-*tert*-butoxycarbonyl-6-*exo*-(*N,N*-dibenzylamino)-3-azabicyclo[3.1.0]hexane (10d): 3-*tert*-butoxycarbonyl-6-*exo*-amino-3-azabicyclo[3.1.0]hexane (10f): Hydrogen was passed through the mixture of 10% Pd/C (0.50 g, 11 mol%) in MeOH (10 mL) over 1 h, and a solution of 3-*tert*-butoxycarbonyl-6-*exo*-(dibenzylamino)-3-azabicyclo[3.1.0]hexane (**10d**) (1.56 g, 4.12 mmol) in methanol (15 mL) was added in one portion, and hydrogen was passed through the stirred suspension for additional 12 h. The catalyst was removed by using a celite pad, which was then washed with methanol (20 mL). The combined filtrates were evaporated at reduced pressure affording **10f** as a colorless solid (803 mg, 98%). M.p. 41 °C. ^{1}H NMR (C_6D_6): $\delta = 1.10–1.25$ (bm, 2H), 1.46 (s, 9H), 1.68 (t, $J = 2.0$ Hz, 1H), 1.71 (bs, 2H), 3.10 (dd, $J = 3.7$, 10.4 Hz, 1H), 3.25 (dd, $J = 3.9$, 10.9 Hz, 1H), 3.38 (d, $J = 10.5$ Hz, 1H), 3.65 ppm (d, $J = 10.9$ Hz, 1H); ^{13}C NMR ($CDCl_3$): $\delta = 25.4$, 26.2, 28.5, 35.5, 48.0, 78.7, 154.2 ppm; HRMS calcd for $C_{10}H_{18}N_2O_2$ 198.1368, found 198.1368; MS (CI$^+$): *m/z* (%): 198 (2), 142 (12), 125 (12), 69 (100), 57 (28); elemental analysis calcd (%) for $C_{10}H_{18}N_2O_2$ (198.3): C 60.58, H 9.15; found: C 59.65, H 9.15. X-ray crystal structure analysis: see below.[20]

Carried out on larger scale, this hydrogenative debenzylation of **10d** (35.0 g, 92.4 mmol) with Pd/C (10%, Merck Lot S 30499–135) (3.0 g, 2.8 mmol) gave **10f** (18.0 g; 98%).

6-*exo*-*N,N*-Dibenzylamino-3-azabicyclo[3.1.0]hexane (10g): A solution of 3-*N*-*tert*-butoxycarbonyl-6-*exo*-*N,N*-dibenzylamino-3-azabicyclo[3.1.0]hexane (**10d**) (10 g, 26.4 mmol) in trifluoroacetic acid (20 mL, 261 mmol) was stirred at ambient temperature for 1 h. The excess trifluoroacetic acid was evaporated under reduced pressure, and the residue taken up in methanol (30 mL). Poly-4-vinylpyridine (5.0 g) was added to this solution, and the mixture was stirred for 1 h. The solution was filtered, and the solvent

evaporated under reduced pressure to give **10g** (7.21 g; 98%) as a light yellow solid, m.p. 68.0 °C. ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 1.86$ (bs, 2H, 1-H, 5-H), 2.69 (bs, 1H, 6-H), 3.08 (bs, 4H, 2-H, 4-H), 4.21 (s, 4H, benzyl-H), 7.31–7.43 ppm (m, 10H, aryl-H); ^{13}C NMR (50.3 MHz, $CDCl_3$, additional APT): $\delta = 22.7$ (+), 41.9 (+), 46.6 (−), 60.2 (−), 129.1 (+), 129.9 (+), 130.1 (−), 131.1 (+); MS (EI): *m/z* (%): 278 (10), 249 (20), 187 (41), 158 (39), 131 (8), 91 (100), 41 (9); elemental analysis calcd (%) for $C_{19}H_{22}N_2$ (278.2): C 82.09, H 7.98; found: C 82.24, H 7.72.

***N*-Benzyl-3-isopropylpyrrolidine (18)**: Isopropylmagnesium chloride (15.3 mL, 30.2 mmol, 1.96 M in THF) was added within 10 min to a solution of [Ti(O*i*Pr)$_4$] (3.05 mL, 10.4 mmol) and *N*-benzyl-3-pyrroline[35] (**15a**) (1.50 g, 9.4 mmol) in anhydrous THF (40 mL) under an atmosphere of nitrogen at ambient temperature. The mixture was heated under reflux for 30 min, and then the reaction was quenched by addition of water (50 mL) to the hot mixture. Stirring was continued until the precipitate had turned colorless. The precipitate was removed by filtration and washed with diethyl ether (2 × 30 mL). The combined filtrates were dried ($MgSO_4$) and concentrated under reduced pressure, giving a residue that was subjected to flash column chromatography (hexane/EtOAc 10:1) on silica gel to give four fractions. Fraction I, after Kugelrohr distillation (0.602 g) consisted of the title compound **18** and *N*-benzylpyrrole in a ratio of 12.5:1 (according to ^{1}H NMR spectroscopy). Fraction II (0.212 g) was pure **18**.[36] Fraction III (0.127 g) contained **18**, *N*-benzylpyrrolidine,[37] the starting material **15**, and an unidentified compound in a ratio of 9:8:1:2. The total amount of **18** in these fractions corresponds to a yield of 44%. ^{1}H NMR ($CDCl_3$): $\delta = 0.85$ (d, $J = 6.6$ Hz, 3H), 0.88 (d, $J = 6.6$ Hz, 3H) 1.40–1.60 (m, 2H), 1.90–2.05 (m, 1H), 2.05–2.15 (m, 2H), 2.35–2.45 (m, 1H), 2.80–3.00 (m, 2H), 3.61 (d, $J = 12.7$ Hz, 1H), 3.67 (d, $J = 12.7$ Hz, 1H), 7.25–7.34 ppm (m, 5H); ^{13}C NMR ($CDCl_3$): $\delta = 21.2$, 21.3, 29.0, 33.0, 45.4, 54.3, 59.1, 61.0, 126.8, 128.2, 128.8, 139.3 ppm; HRMS calcd for $C_{14}H_{21}N$ 203.1673, found 203.1673; MS (EI$^+$): *m/z* (%): 203 (75), 188 (4), 175 (2), 160 (8), 132 (16), 126 (32), 112 (43), 106 (3), 91 (100); elemental analysis calcd (%) for $C_{14}H_{21}N$ (203.3): C 82.69, H 10.42; found: C 82.42, H 10.16.

When the same reaction was carried out with isopropylmagnesium bromide instead of the chloride, **18** was obtained in 77% yield and in addition contaminated with a small amount of *N*-benzylpyrrole (less than 5 mol%) and *N*-benzylpyrrolidine (about 20 mol%, according to ^{1}H NMR spectroscopy).

1,1′-Bicyclohexyl (71): A solution of cyclohexylmagnesium bromide was prepared from magnesium turnings (1.20 g, 50 mmol) and cyclohexyl bromide (8.2 g, 50 mmol) in anhydrous THF (50 mL). According to titration, this solution was 0.67 M. An aliquot (10 mL) was quenched with 10% aqueous H_2SO_4 (100 mL), and the mixture was extracted with Et_2O (100 mL), dried over Mg_2SO_4, and filtered. The combined filtrates were evaporated under reduced pressure and the residue subjected to Kugelrohr distillation (40–50 °C/0.05 Torr), affording **71** (0.33 g; 59%) as a colorless oil. ^{1}H NMR ($CDCl_3$): $\delta = 0.86$–1.10 (m, 6H), 1.10–1.36 (m, 6H), 1.58–1.86 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 26.9$, 30.2, 43.5 ppm; HRMS calcd for $C_{12}H_{22}$ 166.1721, found 166.1721; MS (EI$^+$): *m/z* (%): 166 (15), 104 (7), 91 (15), 83 (96), 81 (31), 67 (28), 55 (84), 41 (100).

Cyclohexyl(*N*,*N*-dibenzylamino)methane (76): Benzyl bromide (2.21 mL, 18.6 mmol) was added dropwise over 25 min at 0–5 °C under an atmosphere of argon to a solution of cyclohexylmethyl)amine (1.00 g, 8.83 mmol) and triethylamine (2.59 mL, 18.6 mmol) in anhydrous dichloromethane (20 mL). The mixture was allowed to warm to room temperature over 24 h, then heated under reflux for 4 h. The solvent was evaporated, water (20 mL) and *tert*-butyl methyl ether (20 mL) was added and to the residue. The organic layer was dried ($MgSO_4$) and concentrated to give a residue that was subjected to radial chromatography (*tert*-butyl methyl ether/*n*-hexane, 1:9), affording **76** (726 mg; 28%) as a colorless solid which was recrystallized from *n*-hexane at −78 °C, m.p. 60 °C (ref. [28] 50 °C). ^{1}H NMR ($CDCl_3$): $\delta = 0.65$–0.83 (m, 2H), 0.90–1.30 (m, 3H), 1.50–1.80 (m 4H), 1.80–2.06 (m, 2H), 2.18 (d, $J = 7.4$ Hz, 2H), 3.50 (s, 4H), 7.13–7.46 ppm (m, 10H); ^{13}C NMR ($CDCl_3$): $\delta = 26.3$, 26.9, 31.7, 35.8, 58.9, 60.9, 126.7, 128.1, 128.8, 140.2 ppm; HRMS calcd for $C_{21}H_{27}N$ 293.2143, found: 293.2143); MS (EI$^+$): *m/z* (%): 293 (6), 210 (100), 200 (3), 181 (11), 118 (4), 106 (3), 91 (85).

Crystal structure determinations: Suitable crystals were grown by slow cooling of a saturated solution in pentane with a few drops of Et_2O (**10d**), by evaporation of a methanol solution (**10f**), by sublimation (**10e**), and by slow concentration of a dilute solution in hexane (**28**). The data were collected on a STOE AED2 diffractometer using graphite-monochromated $Mo_{K\alpha}$ radiation. The structure solutions and refinements were performed with the SHELX program suite (Version 5.10).[20b] All non-hydrogen atoms were refined anisotropically. The hydrogen atoms were located in a difference Fourier map and refined as riding groups with the 1.2 fold isotropic displacement parameter of the corresponding C atom. Relevant parameters of crystal data collections and structure refinements are presented in Table 4.

Table 4. Crystal and data collection parameters for compounds **10d–f**, and **28**.

	10d	**10e**	**10f**	**28**
formula	$C_{24}H_{30}N_2O_2$	$C_5H_{10}N_2$	$C_{10}H_{18}N_2O_2$	$C_{38}H_{42}N_2$
molecular mass	378.50	98.15	198.26	526.74
temperature [K]	203(2)	150(2)	150(2)	152(2)
crystals	monoclinic	monoclinic	monoclinic	monoclinic
crystal size [× 10 mm]	8 × 6 × 4	10 × 8 × 1	7 × 5 × 5	6 × 4 × 2
space group	*P*2(1)/*n*	*Cc*	*P*2(1)	*P*2(1)/*n*
a [Å]	8.7624(18)	9.501(2)	8.3030(17)	12.563(2)
b [Å]	27.821(9)	5.7455(11)	5.9438(12)	9.632(3)
c [Å]	8.8431(18)	10.150(2)	11.349(2)	12.690(2)
α [°]	90	90	90	90
β [°]	99.224(14)	103.50(3)	93.56(3)	99.82(2)
γ [°]	90	90	90	90
V [Å^3]	2127.9(9)	538.8(2)	559.0(2)	1513.1(5)
Z	4	4	2	2
F (000)	816	216	216	568
ρ [g cm^{-3}]	1.181	1.210	1.178	1.156
μ [mm^{-1}]	0.075	0.076	0.082	0.066
T [K]	203(2)	150(2)	150(2)	153(2)
θ_{max} [°]	25.26	27.51	25.00	25.02
refl. collected	5010	1542	2170	4445
refl. independent	3742	1241	1965	2666
R_{int}	0.0779	0.1135	0.0561	0.0253
w$R_2(F^2)$	0.1193	0.2536	0.1242	0.1064
$R(F)$	0.0502	0.0903	0.0456	0.0632
no. parameters. refined	257	64	130	181
GOF	1.024	1.071	1.107	1.029

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