Guanidinium Ylide Mediated Aziridination from Arylaldehydes: Scope and Limitations in the Formation of Unactivated 3-Arylaziridine-2-carboxylates

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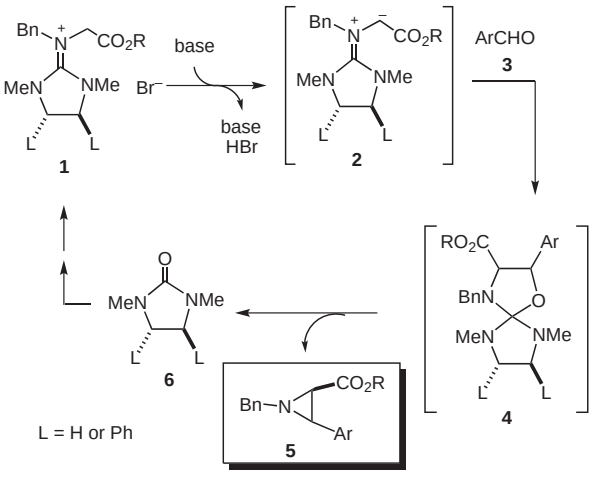
Abstract: The scope and limitations of guanidinium ylide mediated aziridinations from arylaldehydes yielding unactivated 3-arylaziridine-2-carboxylates, applicable to asymmetric synthesis, are discussed.

Key words: aldehydes, asymmetric synthesis, chiral auxiliaries, esters, ylides

Aziridine is the smallest nitrogen-containing heterocycle with a highly strained three-membered system.[1] Owing to its high reactivity, the aziridine unit not only plays an important role in biological actions, such as being responsible for the mode of action in the antitumor activity of mitomycin, but also is used as a versatile synthetic precursor for biologically important nitrogen-containing compounds, especially 3-substituted aziridine-2-carboxylates for amino acid derivatives through a ring-opening reaction.[2] Thus, although a variety of aziridine preparation methods involving asymmetric synthesis have been developed, they are basically classified into three approaches:[1] (1) cyclization of β-amino alcohol derivatives under nucleophilic substitution, (2) cycloaddition of carbenes to imines, and (3) cycloaddition of nitrenes to olefins.

In 2001[1], we[3] made a preliminarily report of a new synthetic method for the preparation of 3-aryl-1-benzylaziridine-2-carboxylates **5** from guanidinium salts **1**, which incorporated an *N*-benzylglycine unit in the 2-position of an imidazolidine skeleton, and aryl- and heteroarylaldehydes **3**, possibly through the corresponding guanidinium ylides **2** by treatment with a base (Scheme 1). This aziridination can be extended to an asymmetric version by introduction of chiral center(s) in the guanidinium templates (e.g., L = Ph). In this unique cycle, unactivated 3-arylaziridine-2-carboxylates **5** are generated with excellent to moderate stereoselectivity depending upon the choice of arylaldehydes **3**, and urea **6** is also co-produced as a recyclable synthetic precursor for the guanidinium salt **1**. In general, *trans*-aziridines are efficiently obtained with satisfactory enantioselectivity when arylaldehydes bearing an electron-donating group such as piperonal [3,4-(methylenendioxy)benzaldehyde, **3a**] are used as the electrophile, whereas *cis*-aziridines are obtained as the major isomer when arylaldehydes bearing an electron-withdrawing group, such as 4-chlorobenzaldehyde (**3g**), are used. Based on these stereochemical results, we tentatively postulated a mechanism for the asymmetric induction through spiro intermediates **4** formed by formal 1,3-dipolar cycloaddition between the guanidinium ylide **2** and an arylaldehyde **3**. Precise examination of this asymmetric aziridination using a variety of 4-substituted benzaldehydes allowed us to propose more reasonable mechanisms to cover the overall aziridine preparation from guanidinium ylides by application of the Hammett relation.[4] Furthermore, we succeeded in expanding this aryl aziridination to an alkenyl (or alkynyl) version by the use of unsaturated aldehydes[5] in place of arylaldehydes as the electrophile, and fully characterized a spiro intermediate like **4** in the reaction with α-bromocinnamaldehyde as a crystalline product.[5b] Thus, although we have fragmentally reported the application of this guanidinium ylide participated asymmetric aziridination to natural product synthesis[5a,6] in addition to approaches to the reaction potentials of the aziridine systems formed,[3–5,7] we discuss here the scope and limitations of aryl aziridinations, partly including the previous data reported as a preliminary communication[3] as the backbone to this new methodology for the preparation of nitrogen-containing three-membered heterocycles.



Scheme 1 Cycle aziridination from guanidinium salt **1** and arylaldehyde **3** through a spiro adduct **4**

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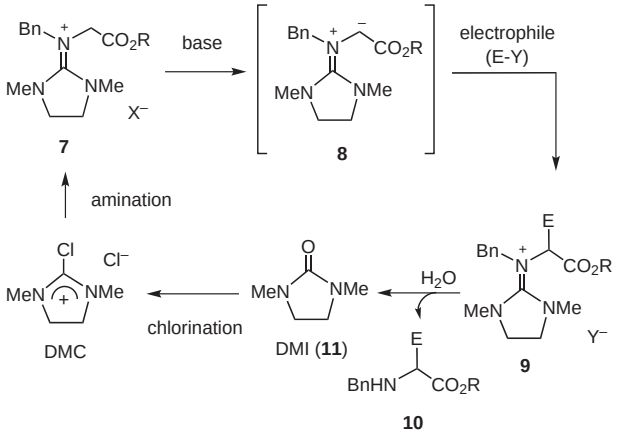
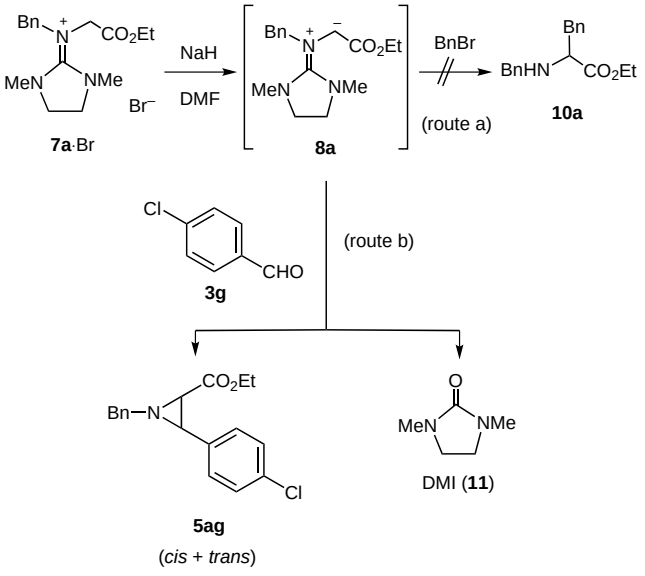
We[8] studied guanidine chemistry focusing on their potential utility in synthesis, such as their use as organocatalysts. Thus, general preparative methods for modified guanidines[9] have been established by applying the multifunctionality of 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (DMC),[10] and the guanidine-participated asymmetric synthesis[11] examined have been reported. Guanidinium salts can also be prepared by either quaternization of guanidines with alkyl halides or direct amination of 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride type compounds with secondary amines.[10a] It was reasonable to expect that guanidinium ylides, derived from the corresponding guanidinium salts by treatment with base, are resonance-stabilized equivalents of azomethine ylides, which could show unique reactivity, for example as dipoles in 1,3-dipolar cycloaddition reactions with unsaturated compounds. To the best of our knowledge, there has been only one literature report[12] on guanidinium ylides at the start of our research work; the synthetic utility of guanidinium ylides was unknown because the literature had only reported their physicochemical properties. Thus, we decided to uncover the reactivity of guanidinium ylides focusing on a new type of preparation of α-substituted α-amino acid derivatives through C–C bond formation reactions with carbon electrophiles; this concept is shown in Scheme 2. Guanidinium salt **7** containing an *N*-benzylglycinate ester unit was selected as a representative source of ylide **8** not only because of the easy generation of the carbanion under mild conditions due to substitution of an electron-attractive ester function, but also because of the expected formation of versatile α-substituted *N*-benzyl-α-amino ester **10** after hydrolysis of the electrophile-incorporated intermediate **9**. The co-produced urea, 1,3-dimethylimidazolidin-2-one (**11**), could be recycled as a synthetic precursor for the guanidinium salt **7** through 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride.



Scheme 2 Concept for the preparation of α-substituted α-amino ester **10** from guanidinium salt **7**

At first we attempted alkylation of the guanidinium ylide **8a** containing an ethyl ester function (route a in Scheme 3). When the guanidinium bromide containing ethyl *N*-benzylglycinate, **7a**·Br, was treated with sodium hydride in *N*,*N*-dimethylformamide with ice cooling, the reaction mixture turned yellow from colorless, strongly suggesting the formation of a ylide-type compound in situ; however, more positive evidence could not be obtained despite the use of spectroscopic approaches. The yellow reaction mixture formed was then stirred with benzyl bromide as an electrophile under ice cooling with monitoring by thin layer chromatography, but this showed TLC patterns with multiple spots and not the expected formation of ethyl α,*N*-dibenzylglycinate (ethyl *N*-benzylphenylalaninate, **10a**).

Therefore, we turned our attention to an aldol-type reaction using 4-chlorobenzaldehyde (**3g**) as the electrophile in place of alkylation (route b in Scheme 3). Treatment of **7a**·Br with **3g** for 24 hours under the same conditions led to the generation of new products, TLC of which showed three spots: two less polar and one more polar spot than that of the starting aldehyde **3g**. Purification of the products using preparative TLC (PTLC) resulted in the isolation of two products only; these corresponded to the less polar spots on TLC because the more polar spot disappeared during purification. These two products showed the same molecular ion peaks [m/z = 316 (M^+) and 318 ($M^+ + 2$)] in FAB-MS and the presence of common functionalities such as a 1,4-disubstituted benzene ring system, ethyl ester, *N*-benzyl, and two methine units in the ^{1}H and ^{13}C NMR spectra, indicating that these are *cis* and *trans* isomers of ethyl 1-benzyl-3-(4-chlorophenyl)aziridine-2-carboxylate (**5ag**). 1,3-Dimethylimidazolidin-2-one (**11**) was also isolated as the expected co-product. In the ^{1}H NMR spectrum of the less polar aziridine isomer, methine protons were observed as singlets at δ = 2.74 and 3.29, whereas those of the more polar one as doublets (J = 6.7 Hz) at δ = 2.64 and 3.01. In the literature[13] the stereochemistry of 2,3-disubstituted aziridines is assigned by the coupling constant between the C2 and C3 methine



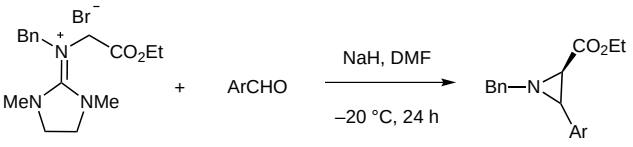
Scheme 3 Trials for alkylation and aldol-type reaction of guanidinium salt **7a**·Br

protons: in general, the *trans* isomer shows $J = \sim 4$ Hz, whereas *cis* isomer $J = \sim 7$ Hz. Thus, a larger coupling constant is observed in the *cis* isomer compared to the *trans*. According to this general rule we concluded that the less polar isomer was *trans*-aziridine-2-carboxylate *trans*-**5ag** and that the more polar one the corresponding *cis* derivative *cis*-**5ag**.

The unexpected formation of aziridine products in the reaction of guanidinium salt **7a**·Br and 4-chlorobenzaldehyde (**3g**) using sodium hydride in *N*,*N*-dimethylformamide made us examine the generality of guanidinium ylide participated aziridination by application to other arylaldehydes (Table 1). Benzaldehyde (**3f**) (entry 3) and arylaldehydes **3** substituted with electron-donating groups (entries 1 and 2) or electron-withdrawing group (entries 4 and 5) served as electrophiles to give the corresponding ethyl 3-arylaziridine-2-carboxylates **5aa**,**ad**,**af**,**ag**,**ak**,**al** in which *trans* isomer predominated.

3-Cinnamylaziridine isomers **5al** were produced in total yield of 50% albeit with low diastereoselectivity (entry 6), in which the *trans* isomer showed a complex signal pattern that was assigned to invertomers[14] in the ^{1}H NMR spectrum. The ratio of invertomers was slightly changed dependent upon temperature measured such as 1:1 at 20 °C, 1:1.1 at 0 °C, 1:1.4 at –30 °C, and 1:1.8 at –90 °C. In NOE experiments of the major invertomer at –90 °C the C2 methine proton showed correlations with not only *N*-benzylmethylene protons but also the 1′-olefinic pro-

Table 1 Reaction of the Guanidinium Salt **7a**·Br with Various Arylaldehydes **3** (NaH, DMF)

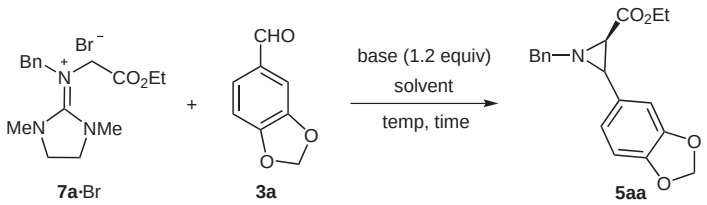


7a·Br **3** **5a**

Entry	Aldehyde **3**	Ar	Product	Yield (%) *cis*	*trans*	Total
1	**3a**	3,4-$(OCH_2O)C_6H_3$	**5aa**	4	66	70
2[a]	**3d**	2-$MeOC_6H_4$	**5ad**	0	54	54
3	**3f**	Ph	**5af**	7	32	39
4	**3g**	4-ClC_6H_4	**5ag**	9	45	54
5	**3k**	4-$O_2NC_6H_4$	**5ak**	0	29	29
6[b]	**3l**	CH=CHPh	**5al**	22	28	50

[a] Treated for 8 h.
[b] Treated for 4 h.

Table 2 Effect of Base on the Aziridinations Using Piperonal (**3a**)



7a·Br **3a** **5aa**

Entry	Base, solvent	Temp, time	Yield (%) *cis*	*trans*	Total
1[a]	NaH, DMF	–20 °C, 23 h	4	66	70
2	Cs_2CO_3, DMF	0 °C → r.t., 24 h	3	47	50
3	Ag_2CO_3, DMF	0 °C → r.t., 24 h	–[b]	19	19
4	K_2CO_3, DMF	–20 °C → r.t., 48 h	0	–[b]	–[b]
5	CsF, DMF	–20 °C → r.t., 5 h	10	–[b]	–[b]
6	*n*-BuLi, THF, HMPA	–78 °C, 8h	1	18	19
7	NaOEt, EtOH	r.t., 1 h	–	–	–
8	TMG, CH_2Cl_2	r.t., 24 h	–	17	17
9[c]	TMG[d]	r.t., 24 h	3	54	57
10	DBU	r.t., 21 h	–	–	–
11	Et_3N	r.t., 22 h	–	–	–

[a] As in Table 1, entry 1.
[b] Detectable on TLC but not isolated.
[c] Without solvent.
[d] Freshly distilled before use.

ton, whereas only correlation between the C2 methine and the 1′-olefinic protons occurred in the minor invertomer. These findings indicated that configuration of the *N*-benzyl group was *cis* to the cinnamyl function in the former, whereas it was *trans* in the latter (Figure 1).

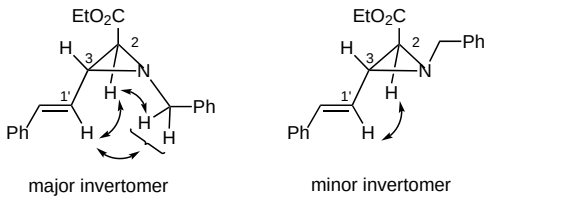
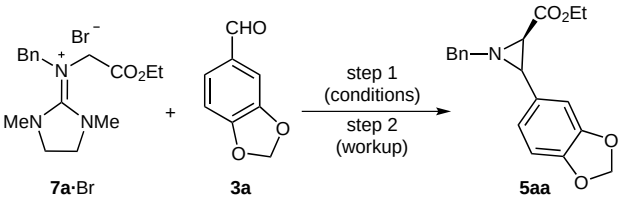


Figure 1 NOE experiments of the *trans*-3-cinnamylaziridine-2-carboxylate *trans*-**5al** at –90 °C

Next, we examined the use of various bases in the aziridination using piperonal (**3a**) as a typical electrophile (Table 2), because it gave the most satisfactory result in Table 1 (entry 1). Treatment with cesium carbonate in *N*,*N*-dimethylformamide afforded the aziridine **5aa** in an even lower yield (entry 2) compared to that with the sodium hydride in *N*,*N*-dimethylformamide system (entry 1), but the results were observed with other carbonates even worse (entries 3 and 4). Tetramethylguanidine (TMG), a typical guanidine-type organobase, could act as an alternative active base, especially when a freshly distilled tetramethylguanidine was used without solvent (entry 9), while no reaction was observed with the use of other amidine-type and amine-type organobases (entries 10 and 11). Thus, we selected sodium hydride in *N*,*N*-dimethylformamide (reaction conditions A) and tetramethylguanidine without solvent (reaction conditions B) as two standard reaction conditions for later aziridination trials.

As discussed above, we detected a polar spot on the TLC of the reaction mixture, which disappeared during purification by PTLC after quenching the reaction by the addition of water. The same phenomenon was also observed during purification by silica gel column chromatography and, in addition, nonreproducible results were often encountered. These findings suggested that the polar component was an intermediate precursor for aziridine products and we, thus, changed the aqueous workup (workup A) to a nonaqueous workup (workup B) as follows: The reaction mixture obtained after stirring for an appropriate time under either the standard reaction conditions A (NaH, DMF) or B (TMG) was concentrated under reduced pressure, dissolved in chloroform, and stirred with silica gel at room temperature until disappearance of the polar spot on TLC. After removal of the silica gel by filtration the filtrate was evaporated under reduced pressure to afford the crude aziridine mixture, which was directly subjected to purification by either PTLC or column chromatography. Comparison results between workups A and B in the aziridination using piperonal (**3a**) are summarized in Table 3 and higher isolation of aziridine products was observed in nonaqueous workup B (entries 1 and 3 vs 2 and 4) regardless of the reaction conditions. Although the chloroform in workup B could be replaced with acetonitrile or methanol (entries 5 and 6), a methoxy-inserted ring-opened product was additionally produced in the latter case. Furthermore, it was found that the quality of the silica gel was basically unimportant, because silica gel was used from several different sources (Fujisilysia, Micro Bead, and Mallinckrodt) and they were equally effective, but basic alumina (Woelm, basic super I) was ineffective (no data shown). Thus, we selected nonaqueous workup B for the conversion of the intermediate polar component into aziridine products.

Table 3 Comparison of Workup Procedures for the Aziridination Using Piperonal (**3a**)

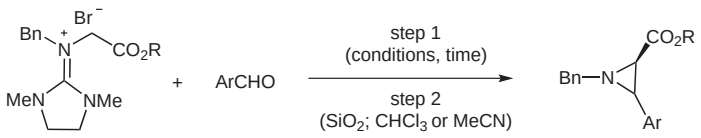


Entry	Step 1 Reaction conditions,[a] temp, time	Step 2 Workup,[b] solvent, time	Yield (%) *cis*	*trans*	Total
1[c]	A, –20 °C, 23 h	A	4	66	70
2	A, –20 °C, 24 h	B, $CHCl_3$, 20 h	8	69	77
3[d]	B, r.t., 22 h	A	3	54	57
4	B, r.t., 24 h	B, $CHCl_3$, 13 h	4	64	68
5	B, r.t., 24 h	B, MeCN, 20 h	3	65	68
6	B, r.t., 24 h	B, MeOH, 26 h	8	49	57[e]

[a] Reaction conditions: A: NaH, DMF; B: TMG without solvent.
[b] Workup A: aqueous; B: nonaqueous (SiO_2).
[c] As Table 1, entry 1.
[d] As Table 2, entry 9.
[e] A methoxy-inserted ring-opened amino ester was additionally produced in 8% yield.

Using the established workup B, we examined the aziridination between two different guanidinium bromides with ethyl, **7a**·Br, or *tert*-butyl, **7b**·Br, ester units as the ylide (nucleophile) source and a variety of arylaldehydes **3** under either reaction conditions A or B (Table 4). Both electron-donating groups (entries 1–12) and electron-withdrawing groups substituted on the benzaldehyde (entries 17–27), and benzaldehyde (**3f**) (entries 13–16) and cinnamaldehyde (**3l**) (entry 28), acted as electrophiles to generally provide aziridines in good yields, except in the case of 4-nitrobenzaldehyde (**3k**) (entries 26 and 27). 3-(Heteroaryl)aziridine-2-carboxylates were also produced in reasonable yields when heteroaryl-substituted aldehydes incorporating indole, pyridine, furan, and benzothiophene skeletons were subjected to the reaction (entries 29–41); however, lower yields of aziridines were obtained in the cases of quinoline and coumarin derivatives (entries 42–45).

Table 4 Aziridinations under Reaction Conditions A or B Followed by Nonaqueous Workup B



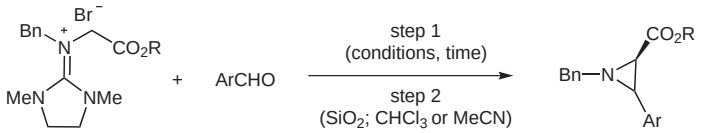
7a·Br R = Et
7b·Br R = *t*-Bu

3

5

Entry	Aldehyde		7	Step 1	Step 2	Product	Yield[c] (%)		
	3	Ar		Reaction conditions,[a] time	Workup,[b] solvent, time		*cis*	*trans*	Total
1[3,d]	**3a**	3,4-$(OCH_2O)C_6H_3$	**7a**·Br	A, 2 h	$CHCl_3$, 20 h	**5aa**	8	69	77
2[3,e]	**3a**	3,4-$(OCH_2O)C_6H_3$	**7a**·Br	B, 24 h	$CHCl_3$, 20 h	**5aa**	4	64	68
3[3]	**3a**	3,4-$(OCH_2O)C_6H_3$	**7b**·Br	A, 24 h	$CHCl_3$, 3 h	**5ba**	8	69	77[f]
4[3]	**3a**	3,4-$(OCH_2O)C_6H_3$	**7b**·Br	B, 24 h	$CHCl_3$, 3 h	**5ba**	6	61	67[f]
5	**3b**	3,4-$(MeO)_2C_6H_3$	**7b**·Br	A, 24 h	MeCN, 4 h	**5bb**	7	56	63
6	**3b**	3,4-$(MeO)_2C_6H_3$	**7b**·Br	B, 24 h	MeCN, 24 h	**5bb**	3	58	61
7[3]	**3c**	4-$MeOC_6H_4$	**7a**·Br	A, 9 h	$CHCl_3$, 20 h	**5ac**	7	78	85
8	**3c**	4-$MeOC_6H_4$	**7b**·Br	A, 24 h	MeCN, 24 h	**5bc**	6	66	71
9[3]	**3d**	2-$MeOC_6H_4$	**7a**·Br	A, 8 h	$CHCl_3$, 20 h	**5ad**	2	93[g]	95
10	**3d**	2-$MeOC_6H_4$	**7b**·Br	A, 8 h	$CHCl_3$, 14 h	**5bd**	4	85	89
11	**3e**	4-$AcHNC_6H_4$	**7b**·Br	A, 7 h	MeCN, 17 h	**5be**	–	77	77
12	**3e**	4-$AcHNC_6H_4$	**7b**·Br	B, 24 h	MeCN, 19 h	**5be**	–	43	43
13[3]	**3f**	Ph	**7a**·Br	A, 24 h	$CHCl_3$, 20 h	**5af**	23	61	84
14[3]	**3f**	Ph	**7a**·Br	B, 24 h	$CHCl_3$, 20 h	**5af**	28	41	69
15	**3f**	Ph	**7b**·Br	A, 24 h	MeCN, 6 h	**5bf**	56	29	85
16[3]	**3f**	Ph	**7b**·Br	B, 19 h	$CHCl_3$, 20 h	**5bf**	57	20	77
17[3]	**3g**	4-ClC_6H_4	**7a**·Br	A, 24 h	$CHCl_3$, 20 h	**5ag**	17	48	65
18[3]	**3g**	4-ClC_6H_4	**7a**·Br	B, 24 h	$CHCl_3$, 20 h	**5ag**	16	45	61
19	**3g**	4-ClC_6H_4	**7b**·Br	A, 2 h	MeCN, 16 h	**5bg**	53	23	76
20[3]	**3g**	4-ClC_6H_4	**7b**·Br	B, 24 h	MeCN, 16 h	**5bg**	47	23	70[f]
21	**3h**	2-ClC_6H_4	**7b**·Br	A, 24 h	MeCN, 20 h	**5bh**	30	38	68
22	**3h**	2-ClC_6H_4	**7b**·Br	B, 24 h	MeCN, 22 h	**5bh**	16	44	60
23	**3i**	4-BrC_6H_4	**7b**·Br	A, 18 h	MeCN, 23 h	**5bi**	44	20	64
24	**3j**	2-BrC_6H_4	**7b**·Br	A, 6 h	MeCN, 12 h	**5bj**	26	47	73
25	**3j**	2-BrC_6H_4	**7b**·Br	B, 24 h	MeCN, 22 h	**5bj**	12	45	57
26[3]	**3k**	4-$O_2NC_6H_4$	**7a**·Br	A, 24 h	$CHCl_3$, 20 h	**5ak**	2	45	47
27[3]	**3k**	4-$O_2NC_6H_4$	**7a**·Br	B, 2 h	$CHCl_3$, 20 h	**5ak**	3	43	46
28[3]	**3l**	CH=CHPh[c]	**7a**·Br	A, 24 h	$CHCl_3$, 20 h	**5al**	17	53[g]	70
29[3]	**3m**	*N*-Boc-indol-2-yl	**7a**·Br	A, 7 h	$CHCl_3$, 20 h	**5am**	4	75[g]	79
30[3]	**3m**	*N*-Boc-indol-2-yl	**7b**·Br	B, 6 h	$CHCl_3$, 20 h	**5bm**	5	57	62[h]
31[3]	**3n**	*N*-Boc-indol-3-yl	**7a**·Br	A, 24 h	$CHCl_3$, 20 h	**5an**	4	72[g]	76

Table 4 Aziridinations under Reaction Conditions A or B Followed by Nonaqueous Workup B (continued)



7a·Br R = Et
7b·Br R = *t*-Bu

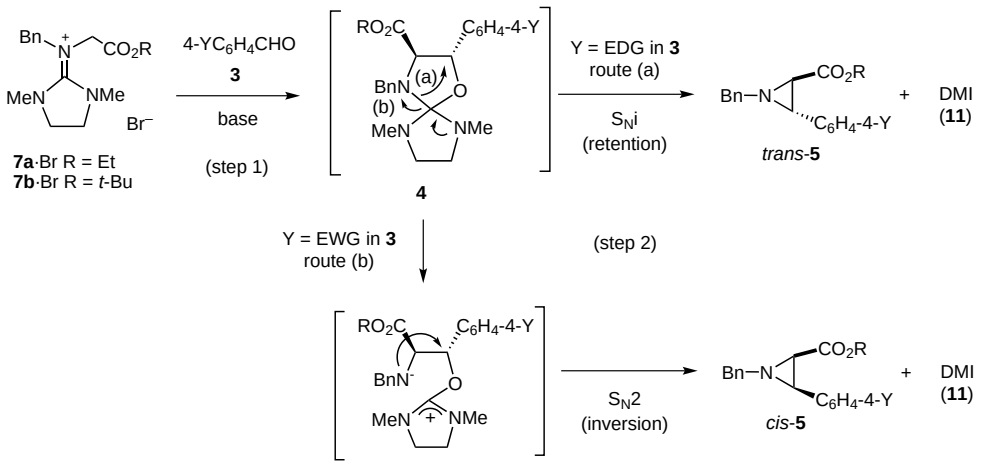
3

5

Entry	Aldehyde **3** Ar	**7**	Step 1 Reaction conditions,[a] time	Step 2 Workup,[b] solvent, time	Product	Yield[c] (%) *cis*	*trans*	Total
32[3]	**3n** *N*-Boc-indol-3-yl	**7b**·Br	B, 24 h	$CHCl_3$, 20 h	**5bn**	2	21	23[i]
33[j]	**3o** *N*-Boc-indol-4-yl	**7a**·Br	A, 24 h	MeCN, 24 h	**5ao**	–	43	43[k]
34[j]	**3o** *N*-Boc-indol-4-yl	**7a**·Br	B, 22 h	MeCN, 72 h	**5bo**	13	62	75
35[j]	**3o** *N*-Boc-indol-4-yl	**7b**·Br	B, 27 h	MeCN, 48 h	**5bo**	8	53	61[l]
36[3]	**3p** pyridin-3-yl	**7a**·Br	A, 7 h	$CHCl_3$, 20 h	**5ap**	8	58	66
37[3]	**3p** pyridin-3-yl	**7b**·Br	A, 4 h	MeCN, 15 h	**5bp**	39	31	70[f]
38	**3q** furan-2-yl	**7b**·Br	A, 3 h	MeCN, 19 h	**5bq**	23	28	51
39	**3q** furan-2-yl	**7b**·Br	B, 24 h	MeCN, 7 h	**5bq**	6	39	55
40	**3r** benzothiophen-3-yl	**7b**·Br	A, 24 h	MeCN, 19 h	**5br**	6	59	65
41	**3r** benzothiophen-3-yl	**7b**·Br	B, 24 h	MeCN, 24 h	**5br**	8	59	67
42	**3s** quinolin-4-yl	**7b**·Br	A, 26 h	MeCN, 18 h	**5bs**	3	32	35
43	**3s** quinolin-4-yl	**7b**·Br	B, 23 h	MeCN, 24 h	**5bs**	–	35	35
44	**3t** 6,7-dimethoxy-2-oxo-2*H*-1-benzopyran-5-yl	**7b**·Br	A, 6 h	$CHCl_3$, 2 h	**5bt**	–	37	37
45	**3t** 6,7-dimethoxy-2-oxo-2*H*-1-benzopyran-5-yl	**7b**·Br	B, 24 h	$CHCl_3$, 4 h	**5bt**	–	12	12

[a] Conditions A: NaH, DMF, –20 °C; B: TMG without solvent, r.t, time.
[b] Workup B: nonaqueous (SiO_2).
[c] Not optimized, isolated yield.
[d] As in Table 3, entry 2.
[e] As in Table 3, entry 4.
[f] The yield reported in the previous paper[3] was improved.
[g] Existed as a mixture of invertomers.
[h] Deprotected indolecarbaldehyde was recovered in 22% yield and a hydroxy-inserted ring-opened α-amino ester was obtained in 3% yield.
[i] Deprotected indolecarbaldehyde was recovered in 73% yield.
[j] A limited amount of THF was used as solvent.
[k] Deprotected indolecarbaldehyde was recovered in 21% together with **3o** (24%).
[l] Starting **3o** (20%) was recovered.

Electron-donating group substituted arylaldehydes (entries 1–12) including *N*-[*tert*-butoxycarbonyl (Boc)]-protected indolecarbaldehydes (entries 29–35) always afforded the *trans*-aziridine as the major isomer independent of the ester function. On the other hand, interestingly, the ratio of *cis*- and *trans*-aziridines was dependent upon the ester function in the reactions of benzaldehyde (**3f**) (entries 13 and 14 vs 15 and 16), 4-chlorobenzaldehyde (**3g**) (entries 17 and 18 vs 19 and 20), and pyridine-3-carbaldehyde (**3p**) (entries 36 vs 37), in which the *cis* isomer was predominantly obtained in the case of the *tert*-butyl ester. These findings could be rationalized by a mechanism[4] proposed in the systematically approached asymmetric aziridination using a range of 4-substituted benzaldehydes, in which the electronic character of the benzylic position in a sterically favored the *trans*-oxazolidine system of a spiro intermediate **4** controlled the formation of the aziridine isomer **5** (Scheme 4). Thus, electron-donating group substituted arylaldehydes mainly afforded *trans*-aziridine *trans*-**5**, with retention of the configuration, by S_Ni mode [route (a)] in the fragmentation of **4**, while *cis*-aziridine *cis*-**5** are formed by S_N2 mode with inversion, after cleavage of the oxazolidine C–N bond in **4** [route (b)], in the case of electron-withdrawing-group-substituted arylaldehydes. The bulkier *tert*-butyl ester would prefer a spiro intermediate **4** with the *trans*-oxazolidine system, compared to the corresponding methyl es-



Scheme 4 Proposed mechanism based on the reported asymmetric aryl aziridination[4]

ter, which results in the predominant formation of the *cis*-aziridine in the reactions of arylaldehydes **3f**,**g**,**p**.

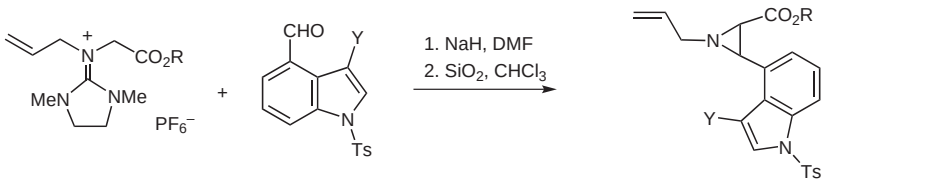
The guanidinium ylide mediated aziridinations obtained in Table 4 can be summarized as follows; (1) substituents on the arylaldehydes are tolerated in the aziridination, (2) the yields are dependent upon the arylaldehyde used, (3) in general, reaction conditions A gave better yields of aziridines than conditions B, and (4) heteroaryl-substituted aldehydes can also served as electrophiles. However, it should be noted here (no data shown), that (1) no reaction occurred with unprotected 4-hydroxybenzaldehyde and indolecarbaldehydes, (2) reactions were unsuccessful with aliphatic aldehydes such as isovaleryl and pivaloyl aldehydes, ethyl polyglyoxalate, trioxane, and paraformaldehyde, and (3) ketone substrates, such as acetophenone derivatives, were also unsuccessful. Unsuccessful aziridinations using aliphatic aldehydes and ketone substrates could also be explained by taking the mechanism shown in Scheme 4 into consideration (no benzylic position and steric repulsion in the oxazolidine system of a spiro intermediate **4**, respectively).

Finally, the aziridination under reaction conditions A was applied to the reaction of *N*-tosylindole-4-carbaldehydes **13** with guanidinium hexafluorophosphates **12** bearing an allyl substituent on the glycinate nitrogen (Scheme 5). The expected 3-(indol-4-yl)aziridine isomers **14** were smoothly afforded in acceptable total yields (84–92%) and the *trans* isomer was mainly formed, albeit with lower diastereoselectivity. Thus, the guanidinium ylide mediated aziridination is potentially applicable to the preparation of a variety of N-modified 3-arylaziridine-2-carboxylates when the glycinate nitrogen is substituted with less-hindered primary alkyl groups.

Aziridination between the guanidinium salt **7a**·Br and piperonal (**3a**) under reaction conditions B was attempted using a catalytic amount of tetramethylguanidine (Table 5). The expected reaction occurred when potassium carbonate was used as an additive in dichloromethane to give *trans*-aziridine *trans*-**5aa** in the same 61% yield as obtained by the stoichiometric version (see, entry 1), albeit a longer reaction time was required (entry 4).

As previously discussed, we have independently recognized that modified chiral guanidines could serve as effective organocatalysts in asymmetric syntheses,[11] such as kinetic silylation of secondary alcohols[11b] and in the Michael addition,[11c] and, as will be discussed later, this guanidinium ylide-mediated aziridination can be extended to an asymmetric version. Thus, we examined the catalytic aziridination in the presence of a chiral guanidine in place of potassium carbonate; however, almost no asymmetric induction was observed in the aziridine products formed (12–33% yields) (no data shown).

In order to evaluate the variation of guanidinium nucleophiles, structure-modified salts were prepared (Scheme



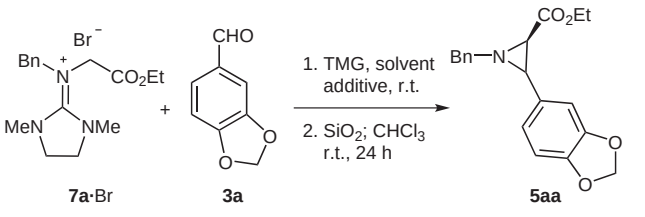
12b R = *t*-Bu
12c R = Me

13a Y = H
13b Y = I

14ca R = Me, Y = H : *trans* (70%); *cis* (17%)
14ba R = *t*-Bu, Y = H : *trans* (55%); *cis* (37%)
14cb R = Me, Y = I : *trans* (60%); *cis* (24%)
14bb R = *t*-Bu, Y = I : *trans* (65%); *cis* (25%)

Scheme 5 Aziridination of *N*-tosylindole-4-carbaldehydes **13** with *N*-allylguanidinium hexafluorophosphates **12**

Table 5 Catalytic Aziridination To Give **5aa**



7a·Br **3a** **5aa**

Entry	TMG (equiv)	Solvent	Additive (2 equiv)	Time (h)	Yield (%)		
					cis	*trans*	Total
1	1.2	–	none	24	6	61	67
2[a]	0.2	–	Et_3N	30	–	–	–
3	0.2	–	K_2CO_3	44	–	–[b]	–[b]
4	0.2	CH_2Cl_2	K_2CO_3	45	–	61	61

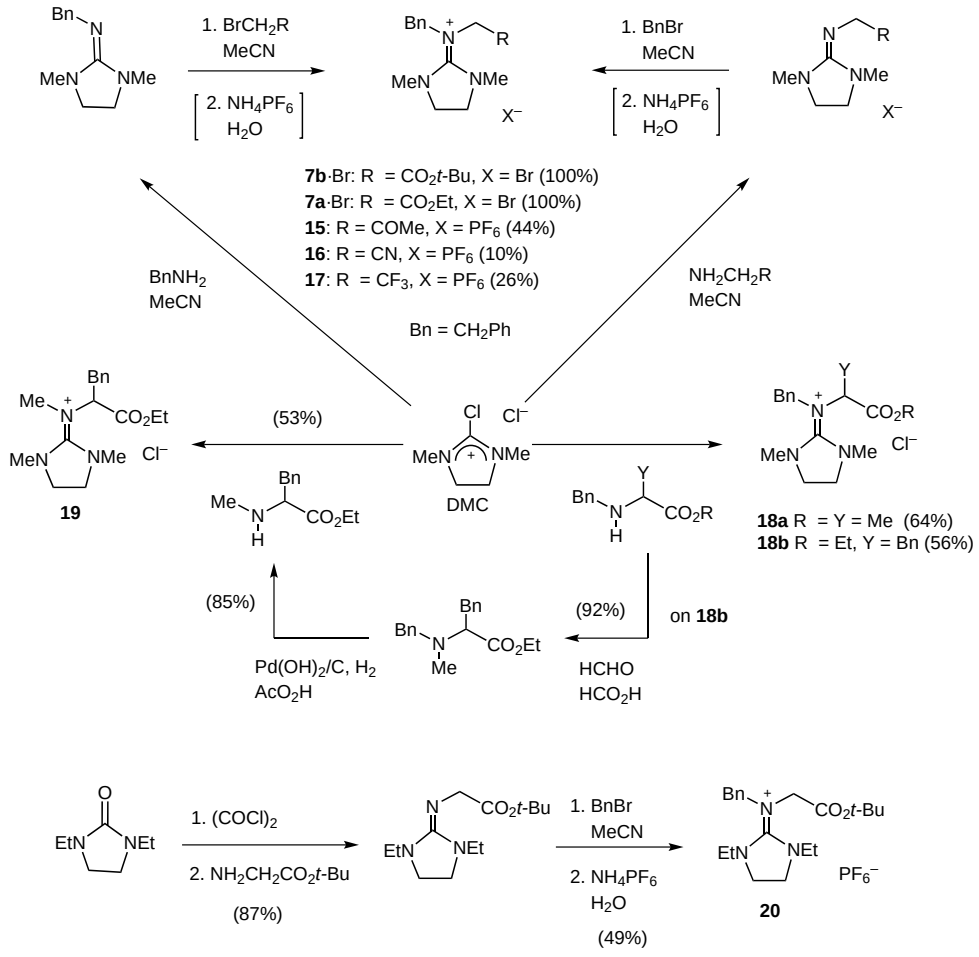
[a] Guanidinium salt decomposed to give a ring-opened urea derivative.
[b] Detectable on TLC but not isolated.

6), in which the preparation of the standard *N*-benzylglycinate-incorporated guanidinium bromides **7a** and **7b** is included for reference. Guanidinium salts with acetyl **15**, nitrile **16**, and trifluoromethyl functions **17**, substituted esters **18** and **19**, and the 1,3-diethylimidazolidine skeleton **20** were targeted as the substrates.

Reactions using modified guanidinium salts **15**–**17** with non-ester functions did not result in the formation of aziridine products. In ^{1}H NMR spectra, functionalized methylene protons (N^+CH_2R) of the guanidinium salts appeared at δ = 3.91 (**16**: R = CN), 3.99 (**17**: R = CF_3), and 4.20 (**15**: R = COMe), respectively, while the corresponding protons in the ethyl ester derivative **7a**·Br were observed at δ = 3.74. The order of the chemical shift should reflect the acidity of these guanidinium derivatives; the lower the chemical shift, the stronger the acidity. Thus, we concluded that the reactivity of ylide functionality derived from the modified guanidinium salts **15**–**17** may be decreased by more effective resonance stabilization compared to the ethyl ester derivative **7a**.

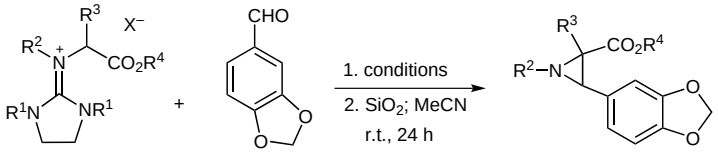
Results on reactions using guanidinium salts **18** and **19** with α-substituted ester functions or 1,3-diethylimidazoline skeleton **20** are given in Table 6.

Although modification of the 1,3-dimethylimidazolidine skeleton **7b** to the corresponding diethyl analogue **20** was tolerated in the aziridination (entries 7 and 8), introduction of a bulky benzyl group (R^3 = Bn) to the α-position of



Scheme 6 Preparation of modified guanidinium salts

Table 6 Aziridination Using Modified Guanidinium Salts and Piperonal (**3a**)



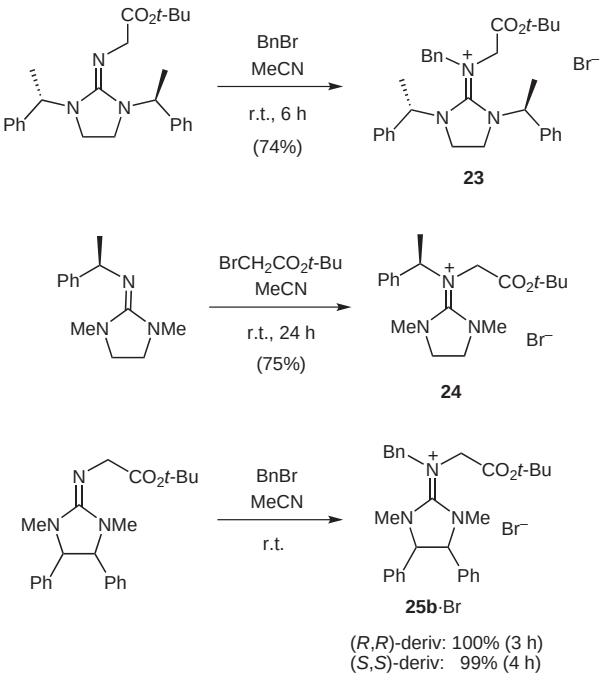
7b·Br, **18**–**20** **3a** **5ba**, **21**, **22**

Entry	Guanidinium salt	R^1	R^2	R^3	R^4	X	Reaction conditions[a]	Product	Yield[b] (%)
1	**18a**	Me	Bn	Me	Me	Cl	A	*trans*-**21**	8[c]
2	**18a**	Me	Bn	Me	Me	Cl	B	*trans*-**21**	43[c]
3	**18b**	Me	Bn	Bn	Et	Cl	A	–	–
4	**18b**	Me	Bn	Bn	Et	Cl	B	–	–
5	**19**	Me	Me	Bn	Et	Cl	A	**22**	3[d]
6	**19**	Me	Me	Bn	Et	Cl	B	**22**	5[d]
7[e]	**20**	Et	Bn	H	*t*-Bu	PF_6	B	*trans*-**5ba**	48
8[f]	**7b**·Br	Me	Bn	H	*t*-Bu	Br	B	*trans*-**5ba**	61

[a] Conditions A: NaH, DMF, –20 °C; B: TMG without solvent, r.t.
[b] Isolated, not optimized yield.
[c] The stereochemical relation between the ester and aryl functions is *trans*.
[d] The stereochemistry was not determined.
[e] The counteranion of guanidinium salt is PF_6^- and $CHCl_3$ was used as the solvent in step 2.
[f] As in Table 4, entry 4; $CHCl_3$ was used as a solvent in the workup.

the ester function remarkably suppressed the reaction (entries 3–6); however, the aziridine was obtained under reaction conditions B in the case of the methyl substituent (R^3 = Me) (entry 2). Thus, it was found that reaction was sensitive to the steric bulkiness of the ylide carbon. The stereochemistry of the aziridine product **21** was deduced to be *trans* between the aryl and ester functions because an NOE enhancement (8.6%) between the C2 methyl protons and the C2 proton of the 3,4-(methylenedioxy)phenyl group was observed.

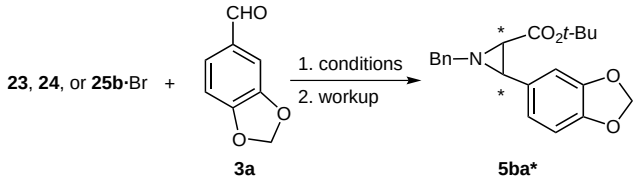
Theoretically, the use of chiral guanidinium templates could expand this new aziridination reaction to an asymmetric version, as previously briefly reported.[3] We prepared three types of chiral guanidinium bromides with a *tert*-butyl N-substituted glycinate function at the 2 position of imidazolidine ring {*tert*-butyl *N*-benzylglycinate incorporated 1,3-bis[(*S*)-1-phenylethyl]imidazolidinium bromide (**23**), *tert*-butyl *N*-[(*R*)-1-phenylethyl]glycinate incorporated 1,3-dimethylimidazolidinium bromide **24**, and an enantiomeric pair of *tert*-butyl *N*-benzylglycinate-incorporated 1,3-dimethyl-5,6-diphenylimidazolidinium bromides[6b] **25b**·Br} from the corresponding chiral guanidine precursors by conventional quaternization with an appropriate alkyl halide (Scheme 7) and screened them for aziridinations with piperonal (**3a**) (Table 7).



Scheme 7 Preparation of three types of guanidinium bromides from chiral guanidines by alkylation

Although disappointing results were encountered with the two guanidinium bromides **23** and **24** (entries 1–3), asymmetric inductions were observed when the third guanidinium bromide **25b**·Br with a 4,5-diphenyl-substitued

Table 7 Screening of Chiral Guanidinium Templates on Asymmetric Aziridination

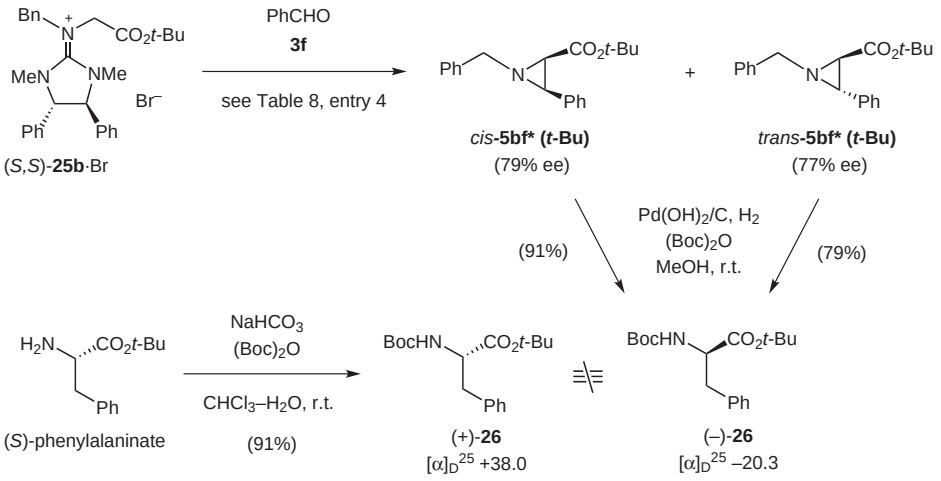


Entry	Guanidinium bromide	Reaction conditions[a]	Workup[b]	Yield (%) *cis*	*trans*
1	**23**	A: –20 °C, 5.5 h	A	–	42 (9% ee)
2	**24**	A: –15 °C, 6 h	A	–[c]	–[c]
3	**24**	B: r.t., 9 h	A	–[c]	–[c]
4	(*R*,*R*)-**25b**·Br	A: –20 °C, 65 h	A	2[d]	45 (61% ee)
5	(*R*,*R*)-**25b**·Br	B: r.t., 3.5 h	A	1[d]	37 (71% ee)
6[3]	(*R*,*R*)-**25b**·Br	A: –20 °C, 39 h	B	7[d]	75 (72% ee)
7	(*R*,*R*)-**25b**·Br	B: –15 °C, 52 h	B	4[d]	49 (45% ee)
8[3]	(*S*,*S*)-**25b**·Br	B[e]: r.t., 4 h	B	6[d]	82 (97% ee)

[a] Conditions: A: NaH, DMF; B: TMG without solvent.
[b] Workup A: aqueous; B: nonaqueous (SiO_2).
[c] Hydrolyzed urea derivative was formed.
[d] The ee was not determined.
[e] TMG was freshly distilled before use.

imidazolidine skeleton was used as the chiral template even under non-optimized aqueous workup A (entries 4 and 5). No improvement was observed under the modified nonaqueous workup B (entries 6 and 7). Satisfactory results were achieved when freshly distilled tetramethylguanidine was used under reaction conditions B (entry 8), in which a chiral *tert*-butyl *trans*-3-[3,4-(methylenedioxy)phenyl]aziridine-2-carboxylate (*trans*-**5ba***) was obtained in 82% yield and with 97% ee. This encouraged us to further examine asymmetric aziridination with the 4,5-diphenylguanidinium bromide **25b**·Br.

The general application of the 4,5-diphenylguanidinium salt induced asymmetric aziridinations was examined by treatment with arylaldehydes in freshly distilled tetramethylguanidine (reaction conditions B) followed by the optimized nonaqueous workup B (Table 8). Excellent to moderate asymmetric inductions were obtained in the screening and, especially, *trans*-3-(*N*-Boc-indol-3-yl)-*trans*-**5bn*** and *trans*-3-(*N*-Boc-indol-4-yl)aziridine-2-carboxylate *trans*-**5bo*** were afforded in 70% and 73% yields with 95% and 93% ee, respectively, when *N*-Boc-indole-3-carbaldehyde **3n** and *N*-Boc-indole-4-carbaldehyde **3o** were subjected to the reaction (entries 7 and 8).



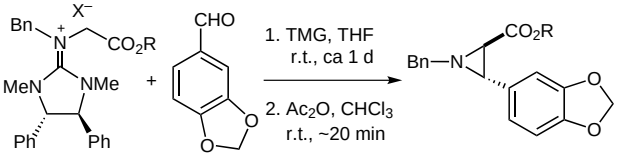
Scheme 8 Absolute configuration of 1-benzyl-3-phenylaziridine-2-carboxylates **5bf*** produced in asymmetric aziridination

Thus, it was found that the 4,5-diphenylguanidinium bromide **25b**·Br effectively served as a chiral auxiliary in the guanidinium ylide mediated asymmetric aziridination.

As previously reported in a preliminary communication,[3] the absolute configuration of chiral centers in *tert*-butyl *cis*- and *trans*-1-benzyl-3-phenylaziridine-2-carboxylates *cis*- and *trans*-**5bf*** was determined by their conversion into phenylalaninates under hydrogenolysis because the *cis* and *trans* isomers were produced with low diastereoselectivities, but reasonable enantioselectivities (see, Table 8, entries 3 and 4). Thus, each aziridine isomer derived from (*S*,*S*)-**25b**·Br (entry 4) was independently subjected to hydrogenolysis in methanol with palladium hydroxide on carbon in the presence of di-*tert*-butyl dicarbonate to give the same (–)-*tert*-butyl *N*-Boc-phenylalaninate (–)-**26** in 91% and 79% yields, respectively (Scheme 8); during the reaction no racemization occurred. These facts indicated that the diastereomeric aziridines *cis*- and *trans*-**5bf*** should have the opposite stereochemistry at C3 but the same stereochemistry at C2. On the other hand, enantiomeric (+)-*tert*-butyl *N*-Boc-phenylalaninate (+)-**26** was derived from commercially available *tert*-butyl (*S*)-phenylalaninate. Therefore, it was concluded that *tert*-butyl *cis*- and *trans*-1-benzyl-3-phenylaziridine-2-carboxylates *cis*- and *trans*-**5bf*** synthesized from the (*S*,*S*)-4,5-diphenylguanidinium bromide (*S*,*S*)-**25b**·Br should have the 2*R*,3*R* and 2*R*,3*S* configurations, respectively.

For evaluation of the ester function and counteranion in an *N*-benzylglycinate-incorporated 1,3-dimethyl-4,5-diphenylimidazolidinium salt, except for the combination of *tert*-butyl ester and bromide **25b**·Br[6b] (see, Scheme 7), three possible guanidinium variants [methyl ester/bromide **25c**·Br, methyl ester/hexafluorophosphate **25c**·PF_6, and *tert*-butyl ester/hexafluorophosphate **25b**·PF_6] were prepared from the corresponding chiral 2-chloro-1,3-dimethylimidazolinium chloride type compound **27**. Preparation of the *S*,*S* enantiomers is shown in Scheme 9 as an example.

Table 9 Effects of an Ester Residue and Counteranion of (*S*,*S*)-Guanidinium Variants (*S*,*S*)-**25** on Asymmetric Aziridination

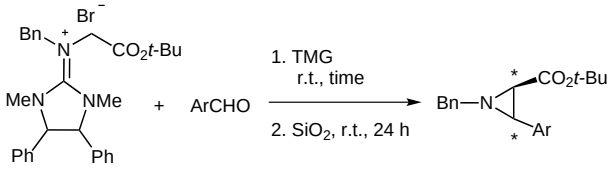


(*S*,*S*)-**25** **3a** *trans*-**5***

Entry	(*S*,*S*)-**25**	R	X	Product	Yield (%)	ee (%)
1	(*S*,*S*)-**25b**·Br	*t*-Bu	Br	*trans*-**5ba***	77	91
2	(*S*,*S*)-**25b**·PF_6	*t*-Bu	PF_6	*trans*-**5ba***	50	19
3	(*S*,*S*)-**25c**·Br	Me	Br	*trans*-**5ca***	69	81[a]
4	(*S*,*S*)-**25c**·PF_6	Me	PF_6	*trans*-**5ca***	50	37

[a] *trans*-**5ca*** was also obtained in 60% yield with 89% ee when the aziridination was conducted under reaction conditions A (NaH in DMF).

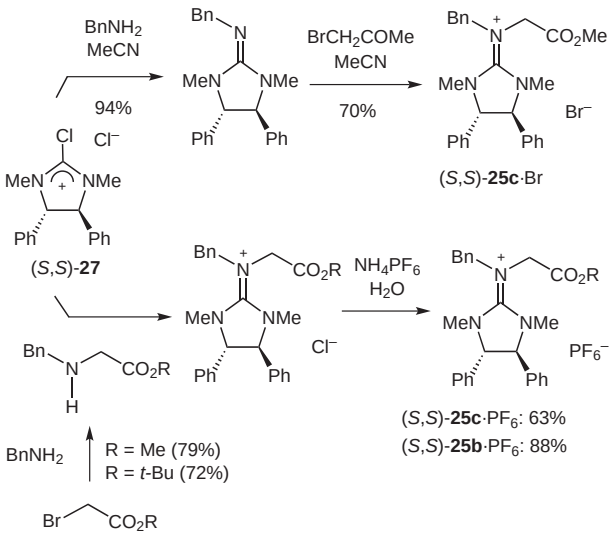
Table 8 Asymmetric Aziridination in Tetramethylguanidine



25b·Br **3** **5b***

Entry	Aldehyde **3**	Ar	**25b**·Br	Time (h)	Product	Yield (%) *cis*	Yield (%) *trans*
1[3,a]	**3a**	3,4-$(OCH_2O)C_6H_3$	(*S*,*S*)	4	**5ba**	6[b]	82 (97% ee)
2	**3b**	3,4-$(MeO)_2C_6H_3$	(*S*,*S*)	4	**5bb**	9[b]	73 (84% ee)
3[3]	**3f**	Ph	(*R*,*R*)	5	**5bf**	61 (75% ee)	32 (73% ee)
4[3]	**3f**	Ph	(*S*,*S*)	3	**5bf**	60 (79% ee)	31 (77% ee)
5[3]	**3g**	4-ClC_6H_4	(*S*,*S*)	4	**5bg**	51[c]	35 (59% ee)
6[3]	**3m**	*N*-Boc-indol-2-yl	(*S*,*S*)	5.5	**5bm**	9[b]	87 (76% ee)
7[3]	**3n**	*N*-Boc-indol-3-yl	(*S*,*S*)	7	**5bn**	6[b]	70 (95% ee)
8[d]	**3o**	*N*-Boc-indol-4-yl	(*R*,*R*)	24	**5bo**	19[b]	73 (93% ee)

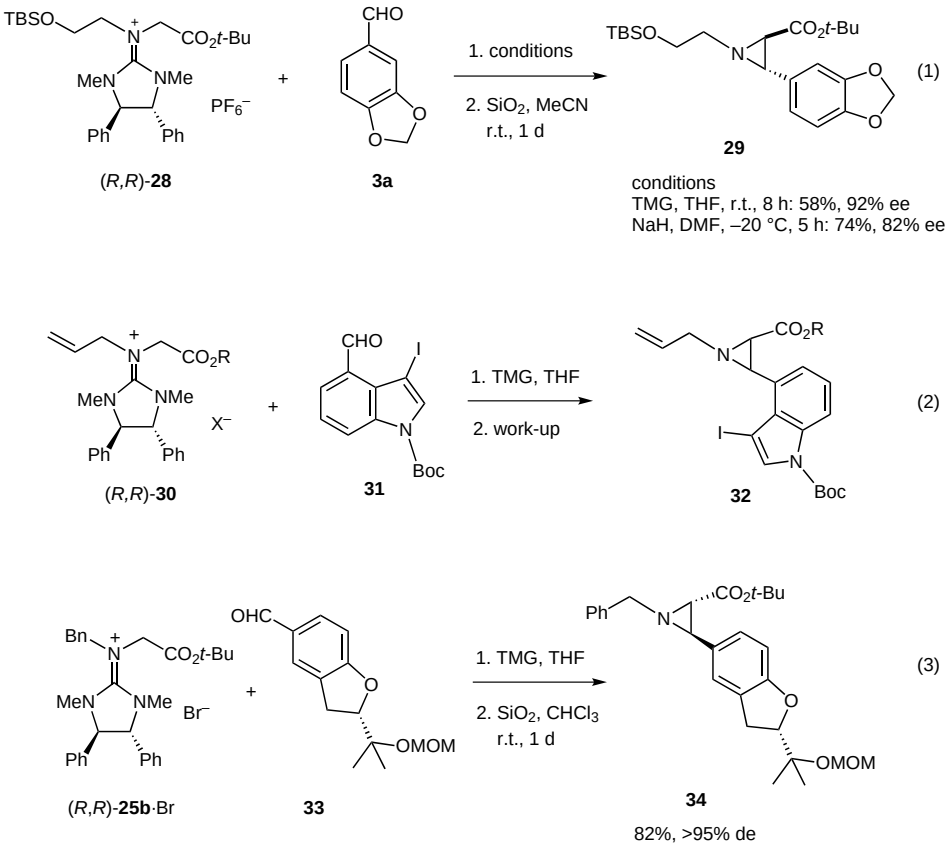
[a] As in Table 7, entry 8.
[b] The ee was not determined.
[c] Retention time (>120 min) was too long under the conditions used.
[d] A limited amount of THF was used as a solvent.[6b]



Scheme 9 Preparation of (*S*,*S*)-guanidinium variants with 4,5-diphenyl pendants

The results on aziridination with these 4,5-diphenylguanidinium salts are summarized in Table 9. A mixture of piperonal (**3a**) and (*S*,*S*)-**25** was stirred with tetramethylguanidine in a limited amount of tetrahydrofuran (modified reaction conditions B)[6b] at room temperature for one day and then the reaction mixture was stirred with acetic anhydride after the addition of excess chloroform (workup C) at room temperature for ca. 20 minutes. Workup C was identified as an alternative nonaqueous decomposition of the intermediate adduct to the aziridine product during examination for substituent effects on aziridination.[4] *tert*-Butyl *trans*-3-[3,4-(methylenedioxy)phenyl]aziridine-2-carboxylate (*trans*-**5ba***) was produced in 77% yield and with 91% ee when piperonal (**3a**) was treated with the *tert*-butyl glycinate incorporated guanidinium bromide (*S*,*S*)-**25b**·Br (entry 1). The enantiomeric excess greatly decreased when the hexafluorophosphate salt was used instead of the bromide (entry 2). A similar tendency was observed in the reactions of the methyl glycinate incorporated variants (entries 3 and 4). Thus, methyl *trans*-3-[3,4-(methylenedioxy)phenyl]aziridine-2-carboxylate (*trans*-**5ca***) was obtained in 69% yield and with 81% ee when (*S*,*S*)-**25c**·Br was used (entry 3), indicating that the bulkiness of the ester function in the 4,5-diphenylguanidinium salts is relatively tolerated in the aziridination (entries 1 and 3).

Finally we applied asymmetric aziridination to either N-modified 4,5-diphenylguanidinium salts with a different substituent at the nitrogen atom from benzyl group or a functionalized aldehyde (Scheme 10, Table 10). (*R*,*R*)-2-(*tert*-Butyldimethylsiloxy)ethyl-substituted guanidinium salt (*R*,*R*)-**28** was subjected to aziridination under modified reaction conditions B (TMG, THF) with piperonal (**3a**) followed by treatment with nonaqueous workup B to afford the corresponding *trans*-aziridine-2-carboxylate **29**



Scheme 10 Asymmetric aziridination using N-modified guanidinium salts and a functionalized aldehyde

Table 10 Aziridinations Using Workup Conditions B or C To Give **32** [Scheme 10 (2)]

Entry	Guanidinium salt	R	X	Workup[a]	Product	Yield (%) *trans*	*cis*
1	(*R*,*R*)-**30c**·Br	Me	Br	B	**32c**	58 (66% ee)	22 (87% ee)
2	(*R*,*R*)-**30c**·Br	Me	Br	C	**32c**	54 (68% ee)	22 (39% ee)
3	(*R*,*R*)-**30c**·PF_6	Me	PF_6	B	**32c**	56 (11% ee)	14 (78% ee)
4	(*R*,*R*)-**30c**·PF_6	Me	PF_6	C	**32c**	55 (15% ee)	18 (66% ee)
5	(*R*,*R*)-**30a**·Br	Et	Br	B	**32a**	47 (56% ee)	17 (94% ee)
6	(*R*,*R*)-**30b**·Br	*t*-Bu	Br	B	**32b**	47 (61% ee)	16 (60% ee)

[a] Workup B: nonaqueous (SiO_2); workup C: nonaqueous (Ac_2O).[4]

in 58% yield and with 92% ee, while slightly lower enantiomeric excess was observed using reaction conditions A (NaH, DMF) but with a higher chemical yield (78%) [(Scheme 10 (1)]. Reaction of the *N*-Boc-3-iodoindole-4-carbaldehyde **31** with *N*-allylglycinate-incorporated guanidinium salts (*R*,*R*)-**30** under modified reaction conditions B also provided the expected aziridine derivatives **32** in reasonable chemical yields (Table 10); however, not only the diastereoselectivity of *cis* and *trans* isomers, but also the enantiomeric excess of the major *trans* isomer were not necessarily good compared to the reactions of *N*-Boc-indolecarbaldehydes without an iodo-substituent with the corresponding *N*-benzyl guanidinium salt **25b**·Br (see, Table 8, entries 6–8), even when different combinations of the ester (R) and the counteranion (X) functions were used. Interestingly, quite high diastereoselectivity (de) was observed in the reaction using a chiral aldehyde [Scheme 10 (3)]. Treatment of (*S*)-dihydrobenzofurancarbaldehyde **33**[15] with a standard chiral guanidinium bromide (*R*,*R*)-**25b**·Br under modified reaction conditions B gave (2*S*,3*R*)-*trans*-aziridine **34** as the sole isolated product in 82% yield.

In conclusion, we have established a new efficient preparation method of unactivated 3-arylaziridine-2-carboxylates from guanidinium ylides carrying a glycinate unit and arylaldehydes, applicable to asymmetric synthesis. However, it is noteworthy that the use of well-purified components, especially the guanidinium salt, is important for successful aziridination because unsatisfactory results were often encountered in the reactions using incompletely purified guanidinium salts even if solidified. It is well known that nitrogen ylides such as ammonium, azomethine, and nitrile ylides are useful in organic synthesis.[12] The results described here indicate that guanidinium ylides are also synthetically versatile nitrogen ylides, and we have developed a promising method for asymmetric amino acid synthesis.

Melting points were determined with a melting point hot-stage instrument and are uncorrected. ^{1}H and ^{13}C NMR spectra were recorded with Jeol 400 and 600 MHz spectrometers in $CDCl_3$. FAB and ESI mass spectra were obtained using a double-focusing magnetic sector mass spectrometer and ToF mass spectrometer, respectively. For column and flash chromatography silica gel 60 (63–210 mm) and NH-coated silica gel (100–200 mesh) and silica gel 60 (40–100 mm), respectively, were used. All reactions were carried out using dry solvents under an argon atmosphere and organic extracts were evaporated under reduced pressure after drying ($MgSO_4$), unless otherwise noted.

Stepwise Preparation of Guanidinium Salts from Primary Amines through Alkylation of Guanidine; General Procedure 1

To a solution of a 2-chloro-4,5-dihydroimidazolium chloride in CH_2Cl_2 was added Et_3N followed by a primary amine at r.t. and the mixture was stirred at r.t. After the addition of ice-water and then 20% aq NaOH solution, the mixture was extracted with toluene. The combined organic solution extracts were washed with H_2O and brine to give a guanidine that was purified by column chromatography (silica gel or NH-silica gel) if necessary. An alkyl bromide was added to a solution of the guanidine in MeCN at r.t. and then the mixture was stirred at r.t. After evaporation of the solvent the residue was isolated either as the bromide by successively washing with hexane and Et_2O or after purified by column chromatography (silica gel) if necessary as the hexafluorophosphate by treatment with aq NH_4PF_6 solution at r.t. Following this procedure gave:

***N*-Benzyl-*N*-[(ethoxycarbonyl)methyl]-*N′*,*N″*-ethylene-*N′*,*N″*-dimethylguanidinium Bromide [7a·Br]; Typical Procedure for GP1**

2-(Benzylimino)-1,3-dimethylimidazolidine

A mixture of 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (4.03 g, 23.8 mmol), Et_3N (7.0 mL, 50.3 mmol), and $BnNH_2$ (1.45 mL, 13.3 mmol) in CH_2Cl_2 (51 mL) was reacted for 5 h and worked up to give guanidine (2.78 g, quant) as a yellow oil.

IR (neat): 1639 cm^{-1}.

^{1}H NMR (400 MHz): δ = 2.84 (s, 6 H), 3.17 (s, 4 H), 4.66 (s, 2 H), 7.17 (t, *J* = 7.9 Hz, 1 H), 7.29 (t, *J* = 7.9 Hz, 2 H), 7.39 (dd, *J* = 7.9, 0.8 Hz, 2 H).

***N*-Benzyl-*N*-[(ethoxycarbonyl)methyl]-*N′*,*N″*-ethylene-*N′*,*N″*-dimethylguanidinium Bromide [7a·Br]**

Treatment of the benzylguanidine (2.90 g, 14.2 mmol) in MeCN (100 mL) with ethyl bromoacetate (1.74 mL, 15.7 mmol) for 5 h followed by washing gave **7a**·Br (5.31 g, quant) as colorless prisms; mp 68–71 °C.

IR (ATR): 1736, 1597 cm^{-1}.

^{1}H NMR (600 MHz): δ = 1.29 (t, *J* = 7.2 Hz, 3 H), 3.22 (s, 6 H), 3.81 (s, 2 H), 4.03 (s, 4 H), 4.23 (q, *J* = 7.2 Hz, 2 H), 4.64 (s, 2 H), 7.32–7.53 (m, 5 H).

^{13}C NMR (150 MHz): δ = 14.0, 36.2, 49.2, 49.7, 54.4, 62.1, 128.8, 129.2, 129.3, 133.7, 164.0, 168.4.

HRMS (ESI): *m*/*z* [M] calcd for $C_{16}H_{24}N_3O_2$: 290.1869; found: 290.1876.

_N_-Benzyl-_N_-[(_tert_-butoxycarbonyl)methyl]-_N′_,_N′′_-ethylene-_N′_,_N′′_-dimethylguanidinium Bromide (7b·Br)
Following GP1: from benzylguanidine (2.89 g, 14.2 mmol) and *tert*-butyl bromoacetate (2.6 mL, 17.6 mmol)] as colorless prisms (washed with Et_2O); yield: 5.73 g (quant); mp 75–77 °C.

_N_-(Acetylmethyl)-_N_-benzyl-_N′_,_N′′_-ethylene-_N′_,_N′′_-dimethylguanidinium Hexafluorophosphate (15)
Following GP1.

Step 1: Benzylguanidine (0.65 g, 3.2 mmol) and bromoacetone (97%, 0.33 mL, 3.8 mmol) gave the guanidinium bromide (0.863 g, 80%).

Step 2: The guanidinium bromide (0.750 g, 2.2 mmol) and NH_4PF_6 (0.481 g, 2.95 mmol) gave **15** (0.77 g, 84%) as colorless prisms (EtOAc–hexane); mp 127–131 °C.

_N_-Benzyl-_N_-(cyanomethyl)-_N′_,_N′′_-ethylene-_N′_,_N′′_-dimethylguanidinium Hexafluorophosphate (16)
Following GP1.

Step 1: 2-Chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (0.52 g, 3.1 mmol) and aminoacetonitrile (97%, 0.274 g, 1.7 mmol) gave the guanidine (0.132 g, 50%).

Step 2: The guanidine (0.394 g, 2.6 mmol) and BnBr (0.31 mL, 2.6 mmol) gave the guanidinium bromide (0.462 g, 55%).

Step 3: The guanidinium bromide (0.115 g, 0.36 mmol) and NH_4PF_6 (0.065 g, 0.40 mmol) gave **16** (0.05 g, 37%) as colorless prisms (EtOAc–hexane); mp 150–152 °C.

_N_-Benzyl-_N′_,_N′′_-ethylene-_N′_,_N′′_-dimethyl-_N_-(2,2,2-trifluoroethyl)guanidinium Hexafluorophosphate (17)
Following GP1.

Step 1: 2-Chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (1.203 g, 7.12 mmol) and 2,2,2-trifluoromethylamine hydrochloride (0.537 g, 3.96 mmol) gave the guanidine (0.696 g, 90%).

Step 2: The guanidine (0.679 g, 3.48 mmol) and BnBr (0.46 mL, 3.87 mmol) gave the guanidinium chloride (0.908 g, 71%).

Step 3: The guanidinium chloride (0.128 g, 0.35 mmol) and NH_4PF_6 (0.064 g, 0.39 mmol) gave **17** (0.06 g, 40%) as colorless prisms (EtOAc–hexane); mp 112–113 °C.

_N_-Benzyl-_N_-[(_tert_-butoxycarbonyl)methyl]-_N′_,_N′′_-diethyl-_N′_,_N′′_-ethyleneguanidinium Hexafluorophosphate (20)
Following GP1.

Step 1: 1,3-Dimethylimidazolin-2-one (5.00 g, 58.2 mmol) and EtI (0.2 mL, 128 mmol) gave 1,3-diethylimidazolin-2-one (6.61 g, 80%).

Step 2: The imidazolidinone (0.503 g, 3.54 mmol) and oxalyl chloride (1.6 mL, 18.3 mmol) gave 2-chloro-1,3-diethyl-4,5-dihydroimidazolium chloride (0.606 g, 88%, 94% purity by ^{1}H NMR).

Step 3: The chloroamidinium chloride (0.589 g, 2.81 mmol, 94% purity) and *tert*-butyl glycinate hydrochloride (0.378 g, 2.25 mmol) gave the guanidine (0.574 g, quant).

Step 4: The guanidine (0.573 g, 2.25 mmol) and BnBr (0.33 mL, 2.77 mmol) gave the guanidinium bromide (0.786 g, 82%).

Step 5: The guanidinium bromide (0.355 g, 0.832 mmol) and NH_4PF_6 (0.149 g, 0.923 mmol) gave **20** (0.243 g, 59%) as colorless prisms; mp 148–150 °C.

_N_-Benzyl-_N_-[(_tert_-butoxycarbonyl)methyl]-_N′_,_N′′_-ethylene-_N′_,_N′′_-bis[(_S_)-1-phenylethyl]guanidinium Bromide (23)
Following GP1: from 2-[(*tert*-butoxycarbonyl)methylimino]-1,3-bis[(*S*)-1-phenylethyl]-4,5-dihydroimidazolidine[9a] (0.06 g, 0.147 mmol) and BnBr (0.02 mL, 0.17 mmol)] gave **23** (0.063 g, 74%) as a colorless amorphous mass.

_N_-[(_tert_-Butoxycarbonyl)methyl]-_N′_,_N′′_-ethylene-_N′_,_N′′_-dimethyl-_N_-[(_R_)-1-phenylethyl]guanidinium Bromide (24)
Following GP1: from 1,3-dimethyl-2-[(*R*)-1-phenethylimino]-4,5-dihydroimidazolidine[9a] (0.052 g, 0.241 mmol) and *tert*-butyl bromoacetate (0.04 mL, 0.271 mmol) gave **24** (0.074 g, 75%) as a brownish oil.

(_S_,_S_)-_N_-Benzyl-_N′_,_N′′_-(1,2-diphenylethylene)-_N_-[(methoxycarbonyl)methyl]-_N′_,_N′′_-dimethylguanidinium Bromide [(_S_,_S_)-25c·Br)]
Following GP1.

Step 1: (*S*,*S*)-**27** (2.45 g, 7.12 mmol) and $BnNH_2$ (0.65 mL, 5.95 mmol) gave the guanidine (1.98 g, 94%).

Step 2: The guanidine (1.99 g, 5.57 mmol) and methyl bromoacetate (0.57 mL, 6.02 mmol) gave (*S*,*S*)-**25c**·Br (1.97 g, 70%) as a pale yellow solid (washed with Et_2O–hexane); mp 122–124 °C.

(_R_,_R_)-_N_-[2-(_tert_-Butyldimethylsiloxy)ethyl]-_N_-[(_tert_-butoxycarbonyl)methyl]-_N′_,_N′′_-(1,2-diphenylethylene)-_N′_,_N′′_-dimethylguanidinium Hexafluorophosphate [(_R_,_R_)-28]

(_R_,_R_)-(Siloxyethyl)guanidine
To an ice-cooled solution of (*R*,*R*)-**27** (5.55 g, 17.3 mmol) in CH_2Cl_2 (40 mL) was successively added Et_3N (7 mL, 50.2 mmol) and a solution of 2-(*tert*-butyldimethylsiloxy)ethylamine[16] (1.83 g, 10.4 mmol) in CH_2Cl_2 (10 mL) and the mixture was stirred at r.t. for 5 h. After the addition of THF (50 mL) the separated solids were removed by filtration. After evaporation of the filtrate, the residue was purified by column chromatography (NH-silica gel, hexane–toluene, 3:1 to toluene–MeOH, 30:1) to give the product (3.45 g, 78%) as a pale yellow oil that solidified on standing; mp 68–70 °C.

$[\alpha]_D^{18}$ –47.9 (*c* 1.0, $CHCl_3$).

IR (ATR): 1669 cm^{-1}.

^{1}H NMR (400 MHz): δ = 0.12 (s, 3 H), 0.13 (s, 3 H), 0.94 (s, 9 H), 2.57 (br s, 3 H), 2.84 (br s, 3 H), 3.57–3.63 (m, 1 H), 3.69–3.80 (m, 2 H), 3.82–3.90 (m, 3 H), 7.13–7.15 (m, 4 H), 7.27–7.34 (m, 6 H).

^{13}C NMR (100 MHz): δ = –5.1, 18.5, 26.0, 29.9, 49.9, 65.8, 70.2, 127.4, 128.0, 128.5, 138.4, 157.5.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{25}H_{38}N_3OSi$: 424.2784; found: 424.2764.

(_R_,_R_)-_N_-[2-(_tert_-Butyldimethylsiloxy)ethyl]-_N_-[(_tert_-butoxycarbonyl)methyl]-_N′_,_N′′_-(1,2-diphenylethylene)-_N′_,_N′′_-dimethylguanidinium Hexafluorophosphate [(_R_,_R_)-28]
The (*R*,*R*)-(siloxyethyl)guanidine (2.70 g, 6.37 mmol) was treated with *tert*-butyl bromoacetate (1.0 mL, 6.77 mmol) in MeCN (20 mL) (12 h). After evaporation CH_2Cl_2 (5 mL), H_2O (20 mL) and NH_4PF_6 (1.11 g, 6.82 mmol) were added. The mixture was stirred (15 min) and extracted with CH_2Cl_2 (4 × 40 mL). The combined organic solutions were washed with H_2O (5 mL) and brine (5 mL), dried (K_2CO_3), and evaporated. Trituration of the residue (hexane–Et_2O, 1:4) afforded (*R*,*R*)-**28** (4.36 g, quant) as a colorless solid; mp 107–115 °C.

$[\alpha]_D^{25}$ –36.4 (*c* 1.0, $CHCl_3$).

IR (ATR): 1742 cm^{-1}.

^{1}H NMR (400 MHz): δ = 0.12 (s, 3 H), 0.14 (s, 3 H), 0.93 (s, 9 H), 1.54 (s, 9 H), 3.05 (s, 6 H), 3.66 (t, *J* = 4.5 Hz, 2 H), 3.95 (dt, *J* = 12.2, 4.5 Hz, 1 H), 4.03 (dt, *J* = 12.2, 4.5 Hz, 1 H), 4.19 (d, *J* = 18.7 Hz, 1 H), 4.52 (dd, *J* = 18.7, 2.2 Hz, 1 H), 4.59 (s, 2 H), 7.24–7.26 (m, 4 H), 7.42–7.44 (m, 6 H).

^{13}C NMR (100 MHz): δ = –5.6, 17.8, 25.5, 27.7, 35.8, 51.3, 54.7, 61.8, 74.2, 83.2, 126.9, 129.1, 129.2, 135.4, 165.0, 167.4.

HRMS (FAB): *m*/*z* [M] calcd for $C_{31}H_{48}N_3O_3Si$: 538.3465; found: 538.3449.

(*R*,*R*)-*N*-Allyl-*N*′,*N*″-(1,2-diphenylethylene)-*N*-[(methoxycarbonyl)methyl]-*N*′,*N*″-dimethylguanidinium Bromide [(*R*,*R*)-30c·Br]

Following GP1.

Step 1: (*R*,*R*)-**27** (0.548 g, 1.71 mmol) and allylamine (0.09 mL, 1.2 mmol) gave allylguanidine (0.346 g, 94%).

Step 2: Allylguanidine (0.500 g, 1.64 mmol) and methyl bromoacetate (0.18 mL, 1.90 mmol) gave (*R*,*R*)-**30c**·Br (0.703 g, 94%) as colorless prisms (washed with Et_2O–hexane); mp 143–145 °C; $[\alpha]_D^{25}$ –70.2 (*c* 1.0, $CHCl_3$).

(*R*,*R*)-*N*-Allyl-*N*′,*N*″-(1,2-diphenylethylene)-*N*-[(methoxycarbonyl)methyl]-*N*′,*N*″-dimethylguanidinium Hexafluorophosphate [(*R*,*R*)-30c·PF_6]

Following GP1: from the allylguanidine (0.501 g, 1.64 mmol) and methyl bromoacetate (0.18 mL, 1.90 mmol), and NH_4PF_6 (0.390 g, 2.40 mmol) gave (*R*,*R*)-**30c**·PF_6 (0.594 g, 69%) as colorless needles (EtOAc); mp 146–148 °C; $[\alpha]_D^{21}$ –46.3 (*c* 1.0, $CHCl_3$).

(*R*,*R*)-*N*-Allyl-*N*′,*N*″-(1,2-diphenylethylene)-*N*-[(ethoxycarbonyl)methyl]-*N*′,*N*′-dimethylguanidinium Bromide [(*R*,*R*)-30a·Br]

Following GP1: from allylguanidine (0.364 g, 1.19 mmol) and ethyl bromoacetate (0.15 mL, 1.36 mmol) gave (*R*,*R*)-**30a**·Br (0.531 g, 94%) as a colorless oil; $[\alpha]_D^{25}$ –75.1 (*c* 1.0, $CHCl_3$).

(*R*,*R*)-*N*-Allyl-*N*-[(*tert*-butoxycarbonyl)methyl]-*N*′,*N*″-(1,2-diphenylethylene)-*N*′,*N*″-dimethylguanidinium Bromide [(*R*,*R*)-30b·Br]

Following GP1: from the allylguanidine (0.371 g, 1.22 mmol) and ethyl bromoacetate (0.20 mL, 1.36 mmol) gave (*R*,*R*)-**30b**·Br (0.523 g, 86%) as a colorless oil, $[\alpha]_D^{25}$ –84.6 (*c* 0.97, $CHCl_3$).

Direct Preparation of Guanidinium Salts from Secondary Amines; General Procedure 2

A solution of a 2-chloroimidazolinium chloride in MeCN was added to an ice-cooled solution of a secondary amine in MeCN containing Et_3N and then the mixture was stirred either at r.t. or under reflux. After removal of insoluble precipitates by filtration, evaporation of the filtrate followed by column chromatography (NH-silica gel) gave a guanidinium chloride. In the case of a hexafluorophosphate salt the residue was treated according to the stepwise procedure given in GP1.

***N*-Allyl-*N*′,*N*″-ethylene-*N*-[(methoxycarbonyl)methyl]-*N*′,*N*″-dimethylguanidinium Hexafluorophosphate (12c); Typical Procedure for GP2**

Treatment of 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (2.90 g, 17.1 mmol) in MeCN (25 mL) with a solution of methyl *N*-allylglycinate (1.42 g, 11.0 mmol) and Et_3N (4.60 mL, 33.0 mmol) in MeCN (110 mL) at r.t. for 3 h followed by a solution of NH_4PF_6 (2.58 g, 15.8 mmol) in H_2O (60 mL) gave **12c** (3.28 g, 80%) as colorless prisms (EtOAc); mp 133–134 °C.

IR (ATR): 1758 cm^{-1}.

^{1}H NMR (400 MHz, acetone-d_6): δ = 3.20 (s, 6 H), 3.73 (s, 3 H), 3.89 (s, 4 H), 4.07 (d, *J* = 6.4 Hz, 2 H), 4.20 (s, 2 H), 5.32 (dd, *J* = 10.1, 0.9 Hz, 1 H), 5.39 (dd, *J* = 17.0, 1.1 Hz, 1 H), 5.88 (ddt, *J* = 17.0, 10.1, 6.9 Hz, 1 H).

^{13}C NMR (100 MHz, acetone-d_6): δ = 36.0, 50.0, 52.8, 54.4, 121.5, 133.1, 164.6, 169.9.

HRMS (ESI): *m*/*z* [M] calcd for $C_{11}H_{20}N_3O_2$: 226.1556; found: 226.1518.

***N*-Allyl-*N*-[(*tert*-butoxycarbonyl)methyl]-*N*′,*N*″-ethylene-*N*′,*N*″-dimethylguanidinium Hexafluorophosphate (12b)**

Following GP2: from 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (0.628 g, 3.71 mmol), *tert*-butyl *N*-allylglycinate (0.302 g, 1.76 mmol), and NH_4PF_6 (0.416 g, 2.55 mmol) gave **12b** (0.450 g, 62%) colorless prisms (EtOAc); mp 93–94 °C.

***N*-Benzyl-*N*′,*N*″-ethylene-*N*-[1-(methoxycarbonyl)ethyl]-*N*′,*N*″-dimethylguanidinium Chloride (18a)**

Following GP2: from 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (1.15 g, 6.81 mmol) and methyl *N*-benzylalaninate (1.013 g, 5.24 mmol)] gave **18a** (1.092 g, 64%) colorless prisms (EtOAc–hexane); mp 97–99 °C.

***N*-Benzyl-*N*-[1-(ethoxycarbonyl)-2-phenylethyl]-*N*′,*N*″-ethylene-*N*′,*N*″-dimethylguanidinium Chloride (18b)**

Following GP2: from 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (0.208 g, 1.23 mmol) and ethyl *N*-benzylphenylalaninate (0.220 g, 0.776 mmol) gave **18b** (0.182 g, 56%) as pale yellow prisms (EtOAc–MeOH); mp 195–196 °C.

***N*-[1-(Ethoxycarbonyl)-2-phenylethyl]-*N*′,*N*″-ethylene-*N*,*N*′,*N*″-trimethylguanidinium Chloride (19)**

Following GP2: from 2-chloro-1,3-dimethyl-4,5-dihydroimidazolium chloride (0.117 g, 0.691 mmol) and ethyl *N*-methylphenylalaninate (0.091 g, 0.437 mmol)] gave **19** (0.079 g, 53%) as pale yellow prisms (EtOAc); mp 71–73 °C.

(*S*,*S*)-*N*-Benzyl-*N*′,*N*″-(1,2-diphenylethylene)-*N*-[(methoxycarbonyl)methyl]-*N*′,*N*″-dimethylguanidinium Hexafluorophosphate [(*S*,*S*)-25c·PF_6]

Following GP2: from (*S*,*S*)-**27** (2.41 g, 7.00 mmol, 93% purity by ^{1}H NMR), methyl *N*-benzylalaninate (0.834 g, 4.66 mmol), and NH_4PF_6 (0.992 g, 1.31 mmol) gave (*S*,*S*)-**25c**·PF_6 (1.734 g, 65%) as colorless prisms (EtOAc); mp 168–169 °C.

(*S*,*S*)-*N*-Benzyl-*N*-[(*tert*-butoxycarbonyl)methyl]-*N*′,*N*″-(1,2-diphenylethylene)-*N*′,*N*″-dimethylguanidinium Hexafluorophosphate [(*S*,*S*)-25b·PF_6]

Reaction of *tert*-butyl bromoacetate and $BnNH_2$ in THF in the presence of Et_3N at r.t. for 20 h gave *tert*-butyl 2-(benzylamino)acetate (72% yield). Et_3N (1.6 mL, 11.5 mmol) and a solution of the above 2-(benzylamino)acetate (0.834 g, 3.8 mmol) in MeCN (6 mL) were successively added to a solution of (*S*,*S*)-**27** (75% purity, 2.386 g, 5.6 mmol) in MeCN (45 mL) at 0 °C and the mixture was stirred at 95 °C (3 h). Workup followed by flash column chromatography ($CHCl_3$–MeOH, 15: 1 to 5:1) gave a pale brown oil, which was treated with NH_4PF_6 (0.803 g, 4.9 mmol) in H_2O (75 mL) (25 min) and triturated (hexane–Et_2O) to afford (*S*,*S*)-**25b**·PF_6 (2.046 g, 88%) as a yellow solid; mp 66–69 °C; $[\alpha]_D^{23}$ +65.0 (*c* 0.50, $CHCl_3$).

IR (ATR): 1747 cm^{-1}.

^{1}H NMR (400 MHz): δ = 1.53 (s, 9 H), 3.07 (s, 6 H), 4.05 (d, *J* = 19.0 Hz, 1 H), 4.21 (d, *J* = 19.0 Hz, 1 H), 4.58 (s, 2 H), 4.62 (d, *J* = 14.6 Hz, 1 H), 4.82 (d, *J* = 14.6 Hz, 1 H), 7.05–7.08 (m, 4 H), 7.34–7.38 (m, 6 H), 7.45–7.54 (m, 5 H).

^{13}C NMR (100 MHz): δ = 27.9, 35.5, 52.1, 55.7, 74.7, 84.0, 127.1, 128.6, 128.8, 129.5, 129.6, 129.7, 133.9, 135.4, 164.3, 167.9.

HRMS (ESI): *m*/*z* [M] calcd for $C_{30}H_{36}F_6N_3O_2P$: 470.2808; found: 470.2822.

Aziridination under Optimized Conditions (Table 4); Reaction Conditions A

A solution of arylaldehyde **3** (1 mmol) in DMF (1–4 mL) was added to a stirred mixture of a guanidinium bromide **7**·Br (1.1–1.3 equiv) and 60% NaH (1.2–1.4 equiv) in DMF (1–2 mL) at –20 °C, and the mixture was stirred at this temperature and worked up. In workup A, the reaction mixture was poured into ice-water and extracted with EtOAc. The combined organic solution extracts were washed with H_2O and brine, and evaporated to give a crude product. In workup B, after evaporation of the reaction mixture, the residue was dissolved in either $CHCl_3$ or MeCN (ca 30 mL) and then stirred with silica gel (ca 20 g) at r.t. for an appropriate time. The silica gel was filtered off and repeatedly washed with either $CHCl_3$ or MeCN. The filtrate and washings were combined and evaporated to give a crude

product. Purification of the latter by column chromatography (silica gel, hexane–EtOAc) afforded an aziridine product **5**.

Aziridination under Optimized Conditions (Table 4); Reaction Conditions B

A mixture of an arylaldehyde **3** (1 mmol) and a guanidinium bromide **7**·Br (1.1 equiv) in freshly distilled TMG (1.1–1.8 equiv) was stirred at r.t. for an appropriate time and evaporated. Treatment of the residue under similar conditions A gave an aziridine product **5**. Data is given for selected racemic aziridine products:

Ethyl 1-Benzyl-3-[3,4-(methylenedioxy)phenyl]aziridine-2-carboxylate (5aa)

***trans*-5aa**
Yellow oil.

IR (neat): 1725 cm^{-1}.

^1H NMR (400 MHz): δ = 1.22 (t, *J* = 7.0 Hz, 3 H), 2.71 (d, *J* = 2.1 Hz, 1 H), 3.26 (br s, 1 H), 4.01 (d, *J* = 13.7 Hz, 1 H), 4.15 (q, *J* = 7.0 Hz, 2 H), 4.23 (d, *J* = 13.7 Hz, 1 H), 5.93 (s, 2 H), 6.72–6.81 (m, 3 H), 7.21–7.42 (m, 5 H).

^{13}C NMR (100 MHz): δ = 14.1, 44.4, 48.3, 54.8, 61.1, 101.0, 106.3, 108.1, 120.0, 126.9, 128.0, 128.2, 132.2, 139.1, 147.1, 147.8, 168.6.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{19}H_{20}NO_4$: 326.1392; found: 326.1402.

***cis*-5aa**
Yellow oil.

IR (neat): 1745 cm^{-1}.

^1H NMR (400 MHz): δ = 1.06 (t, *J* = 7.0 Hz, 3 H), 2.58 (d, *J* = 6.7 Hz, 1 H), 2.99 (d, *J* = 6.7 Hz, 1 H), 3.60 (d, *J* = 13.7 Hz, 1 H), 3.93 (d, *J* = 13.7 Hz, 1 H), 3.94–4.06 (m, 2 H), 5.91 (s, 2 H), 6.70–6.97 (m, 3 H), 7.22–7.46 (m, 5 H).

^{13}C NMR (100 MHz): δ = 14.0, 45.9, 47.6, 60.7, 63.5, 100.9, 107.7, 108.4, 121.2, 127.2, 127.9, 128.4, 128.9, 137.6, 146.9, 147.2, 168.0.

HRMS (ESI): *m*/*z* [M + H] calcd for $C_{19}H_{20}NO_4$: 326.1392; found: 326.1363.

Ethyl 1-Benzyl-3-(2-methoxyphenyl)aziridine-2-carboxylate (5ad)

***trans*-5ad**
Pale yellow oil.

IR (neat): 1726 cm^{-1}.

^1H NMR (600 MHz): δ = 1.21 (t, *J* = 7.2 Hz, 3 H × 5/7), 1.29 (t, *J* = 7.2 Hz, 3 H × 2/7), 2.70 (d, *J* = 2.4 Hz, 1 H × 5/7), 2.72 (br s, 1 H × 2/7), 3.63 (br s, 1 H × 2/7), 3.65 (d, *J* = 2.4 Hz, 1 H × 5/7), 3.74 (s, 3 H × 2/7), 3.82 (s, 3 H × 5/7), 4.10 (d, *J* = 13.7 Hz, 1 H), 4.17 (q, *J* = 7.2 Hz, 2 H), 4.25 (d, *J* = 13.7 Hz, 1 H), 6.82–6.94 (m, 2 H), 7.20–7.40 (m, 7 H).

^{13}C NMR (150 MHz): δ (major invertomer) = 14.16, 43.6, 44.0, 55.3, 61.0, 110.0, 125.0, 126.4, 126.9, 128.1, 128.2, 128.3, 129.8, 138.7, 158.0, 169.0; δ (minor invertomer) = 14.21, 41.7, 44.7, 55.1, 55.5, 61.1, 110.3, 119.8, 126.4, 126.7, 128.1, 128.2, 130.8, 139.4, 159.7, 170.8.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{19}H_{22}NO_3$: 312.1599; found: 312.1578.

***cis*-5ad**
Colorless oil.

IR (ATR): 1746 cm^{-1}.

^1H NMR (400 MHz): δ = 0.95 (t, *J* = 7.2 Hz, 3 H), 2.67 (d, *J* = 7.0 Hz, 1 H), 3.21 (d, *J* = 7.0 Hz, 1 H), 3.62 (d, *J* = 14.0 Hz, 1 H), 3.80 (s, 3 H), 3.83–4.01 (m, 2 H), 3.96 (d, *J* = 14.0 Hz, 1 H), 6.78 (d, *J* = 8.4 Hz, 1 H), 6.89 (dd, *J* = 7.4, 7.4 Hz, 1 H), 7.19 (dd, *J* = 8.4, 7.4 Hz, 1 H), 7.32 (dd, *J* = 7.4, 7.4 Hz, 2 H), 7.43 (d, *J* = 7.4 Hz, 2 H), 7.46 (d, *J* = 7.4 Hz, 1 H).

^{13}C NMR (100 MHz): δ = 13.9, 44.2, 45.2, 55.3, 60.5, 63.8, 109.6, 120.0, 123.4, 127.2, 128.1, 128.3, 128.4, 129.6, 137.9, 157.9, 168.5.

HRMS (ESI): *m*/*z* [M + Na] calcd for $C_{19}H_{21}NO_3Na$: 334.1419; found: 334.1420.

Ethyl 1-Benzyl-3-phenylaziridine-2-carboxylate (5af)

***trans*-5af**[17]
Colorless oil.

IR (neat): 1725 cm^{-1}.

^1H NMR (400 MHz): δ = 1.21 (t, *J* = 7.0 Hz, 3 H), 2.78 (br s, 1 H), 3.32 (br s, 1 H), 4.09 (d, *J* = 14.0 Hz, 1 H), 4.16 (q, *J* = 7.0 Hz, 2 H), 4.26 (d, *J* = 14.0 Hz, 1 H), 7.20–7.38 (m, 10 H).

MS (EI): *m*/*z* (%) = 281 (0.4) [M].

***cis*-5af**[18]
Colorless oil.

IR (neat): 1745 cm^{-1}.

^1H NMR (400 MHz): δ = 0.96 (t, *J* = 7.2 Hz, 3 H), 2.63 (d, *J* = 6.7 Hz, 1 H), 3.07 (d, *J* = 6.7 Hz, 1 H), 3.65 (d, *J* = 13.7 H, 1 H), 3.87–4.02 (m, 3 H), 7.20–7.44 (m, 10 H).

MS (EI): *m*/*z* (%) = 281 (3) [M].

Ethyl 1-Benzyl-3-(4-chlorophenyl)aziridine-2-carboxylate (5ag)

***trans*-5ag**
Yellow oil.

IR (neat): 1726 cm^{-1}.

^1H NMR (500 MHz): δ = 1.22 (t, *J* = 7.0 Hz, 3 H), 2.74 (br s, 1 H), 3.29 (br s, 1 H), 4.08 (d, *J* = 13.7 Hz, 1 H), 4.17 (q, *J* = 7.0 Hz, 2 H), 4.23 (d, *J* = 13.7 Hz, 1 H), 7.21–7.36 (m, 9 H).

^{13}C NMR (125 MHz): δ = 14.1, 44.8, 47.7, 54.8, 61.3, 127.0, 127.6, 128.0, 128.3, 128.5, 133.3, 136.8, 139.0, 168.4.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{18}H_{19}ClNO_2$: 316.1104; found: 316.1112.

***cis*-5ag**
Yellow oil.

IR (neat): 1744 cm^{-1}.

^1H NMR (500 MHz): δ = 1.01 (t, *J* = 7.2 Hz, 3 H), 2.64 (d, *J* = 6.7 Hz, 1 H), 3.01 (d, *J* = 6.7 Hz, 1 H), 3.61 (d, *J* = 13.7 Hz, 1 H), 3.90–4.03 (m, 3 H), 7.23–7.41 (m, 9 H).

^{13}C NMR (125 MHz): δ = 14.0, 46.0, 46.9, 60.8, 63.4, 127.3, 127.9, 128.0, 128.4, 129.2, 133.2, 133.5, 137.5, 167.8.

HRMS (ESI): *m*/*z* [M + H] calcd for $C_{18}H_{19}ClNO_2$: 316.1104; found: 316.1117.

Ethyl 1-Benzyl-3-(4-nitrophenyl)aziridine-2-carboxylate [(5ak)

***trans*-5ak**
Yellow oil.

IR (neat): 1727 cm^{-1}.

^1H NMR (400 MHz): δ = 1.23 (t, *J* = 7.2 Hz, 3 H), 2.80 (d, *J* = 2.1 Hz, 1 H), 3.41 (br s, 1 H), 4.11 (d, *J* = 13.4 Hz, 1 H), 4.19 (q, *J* = 7.2 Hz, 2 H), 4.25 (d, *J* = 13.4 Hz, 1 H), 7.21–7.36 (m, 5 H), 7.46 (d, *J* = 8.5 Hz, 2 H), 8.16 (d, *J* = 8.5 Hz, 2 H).

^{13}C NMR (100 MHz): δ = 14.1, 45.4, 47.2, 54.7, 61.5, 123.6, 127.1, 127.2, 128.0, 128.4, 138.6, 145.8, 147.4, 175.5.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{18}H_{19}N_2O_4$: 327.1345; found: 327.1341.

***cis*-5ak**
Yellow oil.

IR (neat): 1743 cm^{-1}.

^1H NMR (400 MHz): δ = 1.02 (t, *J* = 7.0 Hz, 3 H), 2.74 (d, *J* = 6.8 Hz, 1 H), 3.11 (d, *J* = 6.8 Hz, 1 H), 3.63 (d, *J* = 13.6 Hz, 1 H), 3.89–4.03 (m, 2 H), 4.02 (d, *J* = 13.6 Hz, 1 H), 7.21–7.42 (m, 5 H), 7.58 (d, *J* = 8.5 Hz, 2 H), 8.13 (d, *J* = 8.5 Hz, 2 H).

^{13}C NMR (100 MHz): δ = 14.0, 45.3, 46.7, 61.0, 63.3, 122.8, 123.1, 127.6, 127.9, 128.5, 128.8, 137.1, 142.6, 167.3.

HRMS (ESI): *m*/*z* [M + Na] calcd for $C_{18}H_{18}N_2O_4Na$: 349.1164; found: 349.1172.

Ethyl 1-Benzyl-3-cinnamylaziridine-2-carboxylate (5al)

***trans*-5al**
Yellow oil.

IR (neat): 1725 cm^{-1}.

^1H NMR (500 MHz, CD_2Cl_2, –90 °C): δ (major invertomer) = 1.20 (t, *J* = 7.0 Hz, 3 H), 2.54 (d, *J* = 1.8 Hz, 1 H), 3.09 (dd, *J* = 10.1, 1.8 Hz, 1 H), 3.73 (d, *J* = 14.3 Hz, 1 H), 3.88 (d, *J* = 14.3 Hz, 1 H), 4.05–4.09 (m, 2 H), 6.21 (dd, *J* = 15.5, 10.1 Hz, 1 H), 6.78 (d, *J* = 15.6 Hz, 1 H), 7.20–7.38 (m, 10 H); δ (minor invertomer) = 1.15 (t, *J* = 7.0 Hz, 3 H), 2.71 (d, *J* = 1.8 Hz, 1 H), 2.97 (dd, *J* = 8.9, 1.8 Hz, 1 H), 3.89 (d, *J* = 13.7 Hz, 1 H), 4.05–4.09 (m, 2 H), 4.14 (d, *J* = 13.7 Hz, 1 H), 5.88 (dd, *J* = 16.2, 8.9 Hz, 1 H), 6.67 (d, *J* = 16.2 Hz, 1 H), 7.20–7.38 (m, 10 H).

^{13}C NMR (150 MHz, CD_2Cl_2, 21 °C): δ (1:1) = 14.1, 14.2, 42.4, 45.3, 46.4, 48.5, 54.7, 56.1, 61.2, 121.7, 126.3, 126.4, 127.0, 127.1, 127.66, 127.73, 128.0, 128.1, 128.3, 128.4, 128.6, 128.7, 132.9, 136.1, 136.4, 137.1, 138.4, 140.0, 168.9, 170.3.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{20}H_{22}NO_2$: 308.1651; found: 308.1644.

***cis*-5al**
Yellow oil.

IR (neat): 1741 cm^{-1}.

^1H NMR (500 MHz): δ = 1.26 (t, *J* = 7.0 Hz, 3 H), 2.53 (d, *J* = 6.7 Hz, 1 H), 2.65 (dd, *J* = 8.2, 6.7 Hz, 1 H), 3.69 (d, *J* = 13.7 Hz, 1 H), 3.76 (d, *J* = 13.7 Hz, 1 H), 4.12–4.28 (m, 2 H), 6.26 (dd, *J* = 16.2, 8.2 Hz, 1 H), 6.71 (d, *J* = 16.2 Hz, 1 H), 7.20–7.37 (m, 10 H).

^{13}C NMR (125 MHz): δ = 14.3, 44.7, 48.0, 61.1, 63.3, 124.7, 126.4, 127.2, 127.8, 128.4, 128.5, 134.3, 136.5, 137.5, 169.0.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{20}H_{22}NO_2$: 308.1651; found: 308.1648.

Ethyl 1-Benzyl-3-[1-(*tert*-butoxycarbonyl)indol-4-yl]aziridine-2-carboxylate (5ao)

***trans*-5ao**
Colorless oil.

IR (ATR): 1726 cm^{-1}.

^1H NMR (500 MHz): δ (major invertomer) = 1.22 (t, *J* = 7.1 Hz, 3 H), 1.67 (s, 9 H), 2.92 (d, *J* = 2.0 Hz, 1 H), 3.62 (d, *J* = 2.0 Hz, 1 H), 4.13–4.21 (m, 3 H), 4.32 (d, *J* = 13.9 Hz, 1 H), 6.76 (d, *J* = 3.3 Hz, 1 H), 7.15–7.32 (m, 5 H), 7.40 (d, *J* = 7.3 Hz, 2 H), 7.59 (d, *J* = 3.3 Hz, 1 H), 8.05 (d, *J* = 7.5 Hz, 1 H); δ (minor invertomer) = 1.32 (t, *J* = 7.1 Hz, 3 H), 1.67 (s, 9 H), 2.95 (d, *J* = 2.0 Hz, 1 H), 3.68 (d, *J* = 2.0 Hz, 1 H), 4.13–4.21 (m, 3 H), 4.23 (d, *J* = 13.9 Hz, 1 H), 6.84 (d, *J* = 3.3 Hz, 1 H), 7.15–7.32 (m, 5 H), 7.33 (d, *J* = 7.3 Hz, 2 H), 7.64 (d, *J* = 3.3 Hz, 1 H), 8.21 (d, *J* = 7.5 Hz, 1 H).

^{13}C NMR (125 MHz): δ (major invertomer) = 14.1, 28.2, 43.7, 47.3, 55.1, 61.2, 83.8, 105.2, 114.4, 120.0, 124.3, 126.0, 126.9, 128.1, 128.3, 128.9, 130.2, 135.2, 139.2, 149.7, 168.9; δ (minor invertomer) = 14.3, 28.2, 41.8, 46.0, 55.7, 61.3, 84.0, 105.5, 115.5, 120.0, 123.5, 124.5, 126.6, 127.7, 128.1, 128.9, 131.7, 135.2, 138.5, 149.6, 170.7.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{25}H_{29}N_2O_4$: 421.2127; found: 421.2097.

***cis*-5ao**
Colorless oil.

IR (ATR): 1736 cm^{-1}.

^1H NMR (500 MHz): δ = 0.85 (t, *J* = 7.2 Hz, 3 H), 1.66 (s, 9 H), 2.74 (d, *J* = 6.6 Hz, 1 H), 3.34 (d, *J* = 6.6 Hz, 1 H), 3.73 (d, *J* = 13.8 Hz, 1 H), 3.77–3.92 (m, 2 H), 4.00 (d, *J* = 13.8 Hz, 1 H), 6.70 (d, *J* = 3.6 Hz, 1 H), 7.22–7.36 (m, 5 H), 7.46 (d, *J* = 7.6 Hz, 2 H), 7.57 (d, *J* = 3.6 Hz, 1 H), 8.01 (d, *J* = 8.0 Hz, 1 H).

^{13}C NMR (125 MHz): δ = 13.8, 28.2, 45.3, 46.0, 60.6, 63.8, 83.7, 105.1, 114.3, 122.3, 123.9, 125.8, 127.1, 127.4, 128.1, 128.5, 129.3, 134.8, 137.6, 149.8, 168.2.

HRMS (FAB): *m*/*z* [M + H] calcd for $C_{25}H_{29}N_2O_4$: 421.2127; found: 421.2097.

Methyl 1-Allyl-3-(1-tosylindol-4-yl)aziridine-2-carboxylate (14ca)

***trans*-14ca**
Yellow oil.

IR (ATR): 1730 cm^{-1}.

^1H NMR (400 MHz): δ (major invertomer) = 2.28 (s, 3 H), 2.84 (d, *J* = 1.8 Hz, 1 H), 3.43 (d, *J* = 1.8 Hz, 1 H), 3.55 (dd, *J* = 14.2, 5.5 Hz, 1 H), 3.69–3.83 (m, 4 H), 5.08 (d, *J* = 10.5 Hz, 1 H), 5.23 (d, *J* = 17.4 Hz, 1 H), 5.90–6.00 (m, 1 H), 6.88 (d, *J* = 3.2 Hz, 1 H), 7.08–7.27 (m, 4 H), 7.58 (d, *J* = 3.7 Hz, 1 H), 7.74 (d, *J* = 7.3 Hz, 2 H), 7.91 (d, *J* = 7.8 Hz, 1 H); δ (minor invertomer) = 2.28 (s, 3 H), 2.43 (d, *J* = 8.2 Hz, 1 H), 2.78 (s, 1 H), 2.96 (d, *J* = 10.5 Hz, 1 H), 3.69–3.83 (m, 4 H), 4.84 (d, 16.9 Hz, 1 H), 4.90 (d, *J* = 10.1 Hz, 1 H), 5.76–5.78 (m, 1 H), 6.92 (s, 1 H), 7.08–7.27 (m, 4 H), 7.65 (s, 1 H), 7.74 (d, *J* = 7.3 Hz, 2 H), 8.00 (d, *J* = 7.8 Hz, 1 H).

^{13}C NMR (100 MHz): δ (major invertomer) = 21.3, 43.0, 46.3, 52.0, 53.7, 106.7, 112.5, 116.3, 120.3, 124.4, 124.7, 126.2, 126.6, 129.0, 129.7, 130.6, 134.9, 135.0, 144.8, 168.8; δ (minor invertomer) 21.3, 40.9, 45.3, 52.3, 54.4, 107.1, 113.6, 116.5, 123.8, 123.9, 124.7, 126.6, 126.8, 129.0, 129.7, 131.7, 134.2, 134.6, 145.0, 170.9.

HRMS (ESI): *m*/*z* [M + H] calcd for $C_{22}H_{23}N_2O_4S$: 411.1379; found: 411.1331.

***cis*-14ca**
Yellow prisms; mp 103–105 °C.

IR (ATR): 1747 cm^{-1}.

^1H NMR (400 MHz): δ = 2.33 (s, 3 H), 2.65 (d, *J* = 6.4 Hz, 1 H), 3.10–3.16 (m, 2 H), 3.26 (s, 3 H), 3.35 (dd, *J* = 13.7, 5.5 Hz, 1 H), 5.17 (d, *J* = 10.5 Hz, 1 H), 5.28 (d, *J* = 17.4 Hz, 1 H), 6.03 (ddt, *J* = 16.5, 11.0, 5.5 Hz, 1 H), 6.82 (d, *J* = 3.7 Hz, 1 H), 7.21 (d, *J* = 8.2 Hz, 2 H), 7.25 (t, *J* = 7.8 Hz, 1 H), 7.33 (d, *J* = 6.9 Hz, 1 H), 7.57 (d, *J* = 3.2 Hz, 1 H), 7.75 (d, *J* = 8.2 Hz, 2 H), 7.88 (d, *J* = 8.2 Hz, 1 H).

^{13}C NMR (100 MHz): δ = 21.5, 44.9, 45.5, 51.7, 62.7, 106.7, 112.7, 117.9, 122.5, 124.3, 126.3, 126.8, 127.6, 129.5, 129.8, 133.7, 134.5, 135.2, 144.9, 168.6.

HRMS (ESI): *m*/*z* [M + Na] calcd for $C_{22}H_{22}N_2O_4SNa$: 433.1198; found: 433.1153.

***tert*-Butyl 1-Allyl-3-[3-iodo-1-tosylindol-4-yl]aziridine-2-carboxylate (14bb)**

***trans*-14bb**
Pale yellow prisms; mp 100–101 °C.

IR (ATR): 1721 cm^{-1}.

^{1}H NMR (400 MHz): δ = 1.48 (s, 9 H), 2.36 (s, 3 H), 2.57 (d, *J* = 2.4 Hz, 1 H), 3.65 (dd, *J* = 14.4, 5.4 Hz, 1 H), 3.75 (dd, *J* = 14.7, 5.6 Hz, 1 H), 4.21 (d, *J* = 2.6 Hz, 1 H), 5.12 (d, *J* = 10.4 Hz, 1 H), 5.26 (d, *J* = 17.2 Hz, 1 H), 5.99 (dddd, *J* = 17.2, 10.4, 5.6, 5.4 Hz, 1 H), 7.24–7.31 (m, 3 H), 7.37 (d, *J* = 7.5 Hz, 1 H), 7.74 (s, 1 H), 7.77 (d, *J* = 8.2 Hz, 2 H), 7.90 (d, *J* = 8.2 Hz, 1 H).

^{13}C NMR (100 MHz): δ = 21.6, 28.2, 43.5, 45.5, 53.3, 60.2, 81.7, 112.4, 116.6, 121.6, 125.4, 127.0, 130.0, 131.4 (2 C), 131.9, 134.7 (2 C), 135.5, 145.4, 167.2.

MS (FAB): *m*/*z* = 579 [M + H], 578 [M].

Anal. Calcd for $C_{25}H_{27}IN_2O_4S$: C, 51.91; H, 4.70; N, 4.84. Found: C, 51.81; H, 4.63; N, 4.82.

***cis*-14bb**
Colorless prisms, mp 165–166 °C.

IR (ATR): 1740 cm^{-1}.

^{1}H NMR (400 MHz): δ = 0.83 (s, 9 H), 2.34 (s, 3 H), 2.60 (d, *J* = 6.8 Hz, 1 H), 3.01 (dd, *J* = 13.7, 6.2 Hz, 1 H), 3.52 (dd, *J* = 13.7, 5.5 Hz, 1 H), 3.64 (d, *J* = 6.8 Hz, 1 H), 5.16 (dd, *J* = 10.5, 1.6 Hz, 1 H), 5.29 (dd, *J* = 17.3, 1.7 Hz, 1 H), 6.03 (ddt, *J* = 16.6, 10.4, 5.9 Hz, 1 H), 7.21 (d, *J* = 8.6 Hz, 2 H), 7.29 (t, *J* = 9.1 Hz, 1 H), 7.55 (d, *J* = 7.5 Hz, 1 H), 7.72 (s, 1 H), 7.74 (d, *J* = 8.4 Hz, 2 H), 7.89 (d, *J* = 8.2 Hz, 1 H).

^{13}C NMR (100 MHz): δ = 21.5, 27.3, 44.2, 48.4, 61.0, 62.5, 80.6, 112.4, 117.5, 124.7, 125.1, 126.9, 128.4, 129.0, 129.9, 131.1, 134.2, 134.5, 134.6, 145.2, 166.9.

MS (FAB): *m*/*z* = 579 [M + H].

Anal. Calcd for $C_{25}H_{27}IN_2O_4S$: C, 51.91; H, 4.70; N, 4.84. Found: C, 51.85; H, 4.60; N, 4.77.

***tert*-Butyl 1-[2-(*tert*-Butyldimethylsiloxy)ethyl]-3-[3,4-(methylenedioxy)phenyl]aziridine-2-carboxylate (29); Typical Procedure for Asymmetric Aziridination**
Freshly distilled TMG (0.54 mL, 4.3 mmol) was added to a mixture of (*R*,*R*)-**28** (1.881g, 2.75 mmol) and **3a** (0.379 g, 2.52 mmol) in THF (0.5 mL) and the mixture was stirred at r.t. for 22 h. After addition to a suspension of silica gel (50 g) in MeCN (80 mL), the mixture was stirred at r.t. for 11 h, filtered, and washed with $CHCl_3$ (400 mL). The filtrate was evaporated and the residue was subjected to column chromatography (silica gel, hexane–EtOAc, 30:1 to 20:1) to afford *trans*-**29** (0.617 g, 58%) and *cis*-**29** (0.051 g, 5%).

***trans*-29**
Colorless oil; chiral HPLC [Daicel Chiralcel OD-H, hexane; flow rate: 1.0 mL/min, detection: 254 nm): t_R = 11.7 (minor), 14.3 min (major).

$[\alpha]_D^{17}$ –5.40 (*c* 0.5, $CHCl_3$).

IR (ATR): 1721 cm^{-1}.

^{1}H NMR (400 MHz): δ (major invertomer) = –0.01 (s, 3 H), 0.02 (s, 3 H), 0.85 (s, 9 H), 1.49 (s, 9 H), 2.53 (br s, 1 H), 3.00–3.04 (m, 3 H), 3.80 (br s, 2 H), 5.93 (s, 2 H), 6.74–6.80 (m, 3 H).

^{13}C NMR (100 MHz): δ = –5.42, –5.37, 18.3, 25.9, 28.1, 44.9, 47.7, 53.4, 63.1, 81.6, 100.9, 106.4, 107.9, 120.0, 132.9, 146.8, 147.7, 167.7.

HRMS (EI): *m*/*z* [M] calcd for $C_{22}H_{35}NO_5Si$: 421.2284; found: 421.2285.

***cis*-29**
Colorless oil; chiral HPLC (Daicel Chiralcel OD-H, hexane–*i*-PrOH, 50: 1; flow rate: 1.0 mL/min; detection: 254 nm): t_R = 4.7 (minor), 5.3 min (major).

$[\alpha]_D^{18}$ +15.1 (*c* 0.3, $CHCl_3$).

IR (ATR): 1723 cm^{-1}.

^{1}H NMR (400 MHz): δ = –0.01 (s, 3 H), 0.03 (s, 3 H), 0.83 (s, 9 H), 1.23 (s, 9 H), 2.43 (d, *J* = 7.0 Hz, 1 H), 2.46 (dd, *J* = 11.9, 5.6 Hz, 1 H), 2.85 (dd, *J* = 11.9, 5.6 Hz, 1 H), 2.87 (d, *J* = 7.0 Hz, 1 H), 3.89 (t, *J* = 5.6 Hz, 2 H), 5.91 (s, 2 H), 6.71 (d, *J* = 8.0 Hz, 1 H), 6.85 (dd, *J* = 8.0, 1.4 Hz, 1 H), 6.91 (d, *J* = 1.4 Hz, 1 H).

^{13}C NMR (100 MHz): δ = –5.6, 18.1, 25.8, 27.8, 45.9, 47.0, 62.0, 62.5, 80.9, 100.7, 107.5, 108.6, 121.2, 129.6, 146.5, 146.9, 167.5.

HRMS (EI): *m*/*z* [M] calcd for $C_{22}H_{35}NO_5Si$: 421.2284; found: 421.2295.

Determination of the Absolute Configurations of 3-Phenylaziridine-2-carboxylate 5bf*

***tert*-Butyl *N*-[(*tert*-Butoxycarbonyl)methyl]phenylalaninate (26)**
A mixture of (±)-*cis*-**5bf** (52 mg, 0.168 mmol), $(Boc)_2O$ (40 mg, 0.182 mmol), and $Pd(OH)_2$ on C (16 mg) in MeOH (2 mL) was vigorously stirred at r.t. for 10 h under a H_2 atmosphere; the catalyst was filtered off through Celite. After evaporation of the filtrate the residue was purified by column chromatography (silica gel, hexane–benzene, 15:1 to hexane–Et_2O, 5:1) to give **26** as colorless prisms (50 mg, 92%); mp 91–93 °C; chiral HPLC (Daicel Chiralcel OD-H, hexane–*i*-PrOH, 100:1; detection: 254 nm; flow rate: 1.0 mL/min): t_R = 6.1, 7.5 min.

IR (Nujol): 3352, 1719, 1702, 1648 cm^{-1}.

^{1}H NMR (400 MHz): δ = 1.40 (s, 9 H), 1.42 (s, 9 H), 3.05 (d, *J* = 6.1 Hz, 2 H), 4.45 (dd, *J* = 6.7, 6.1 Hz, 1 H), 4.99 (d, *J* = 6.7 Hz, 1 H), 7.16–7.31 (m, 5 H).

Anal. Calcd for $C_{18}H_{27}NO_4$: C, 67.26; H, 8.47; N, 4.36. Found: C, 67.11; H, 8.45; N, 4.27.

(–)-(*R*)-26
Following the procedure, (–)-*cis*-**5bf*** (104 mg, 0.337 mmol, 79% ee), obtained in the asymmetric aziridination using (*S*,*S*)-**25b**·Br, was hydrogenated with $Pd(OH)_2$ on C (32 mg) in MeOH (2 mL) containing $(Boc)_2O$ (80 mg, 0.368 mmol) for 7 h to give (–)-(*R*)-**26** (99 mg, 91%); 77% ee; mp 91–93 °C; $[\alpha]_D^{25}$ –20.3 (*c* 0.67, CH_2Cl_2).

(+)-(*S*)-26
A solution of $(Boc)_2O$ (44 mg, 0.202 mmol) in $CHCl_3$ (0.5 mL) was added to a mixture of (*S*)-phenylalanine (52 mg, 0.200 mmol), $NaHCO_3$ (18 mg, 0.208 mmol), and NaCl (43 mg) in $CHCl_3$ (1 mL) and H_2O (0.7 mL) and the mixture was stirred at r.t. for 3 h. After removed the separated organic layer, the aqueous layer was extracted with $CHCl_3$. The combined organic layers were washed with H_2O and brine and evaporated. Purification of the residue by column chromatography (silica gel, hexane–benzene, 10:1 to hexane–Et_2O, 5:1) gave (+)-(*S*)-**26** (58 mg, 91%) as colorless prisms; mp 92–93 °C; 100% ee; $[\alpha]_D^{25}$ +38.0 (*c* 1.00, CH_2Cl_2).

Chiral HPLC for Enantiomeric Excess Determination of Selected Aziridine Products
trans-**5ba***: Column: Daicel Chiralcel OD; solvent: hexane–*i*-PrOH (99:1); detection: 254 nm; flow rate: 1.0 mL/min: t_R = 7.9, 9.1 min.

trans-**5bb***: Column: Daicel Chiralcel OD-H; solvent: hexane–*i*-PrOH (250:1); detection: 254 nm; flow rate: 1.0 mL/min: t_R = 10.0, 13.2 min.

cis-**5bb***: Column: Daicel Chiralcel OD-H; solvent: hexane–*i*-PrOH (100:1); detection: 254 nm; flow rate: 1.0 mL/min: t_R = 7.7, 8.5 min.

trans-**5bf***: Column: Daicel Chiralcel OD-H; solvent: hexane–*i*-PrOH (250:1); detection: 254 nm; flow rate: 0.5 mL/min: t_R = 12.1 min, 13.0 min.

cis-**5bf***: Column: Daicel Chiralcel OD-H; solvent: hexane–*i*-PrOH (100:1); detection: 254 nm; flow rate: 1.0 mL/min: t_R = 7.7, 8.5 min.

trans-**5bg***: Column: Daicel Chiralcel OD-H; solvent: hexane–*i*-PrOH (300:1); detection: 254 nm; flow rate: 0.3 mL/min: t_R = 22.9, 24.2 min.

trans-**5bn***: Column: Daicel Chiralcel OD-H; solvent: hexane–*i*-PrOH (100:1); detection: 254 nm; flow rate: 1.0 mL/min: t_R = 4.9, 5.4 min.

trans-**5bm***: Column: Daicel Chiralcel OD-H; solvent: hexane–*i*-PrOH (100:1); detection: 254 nm; flow rate: 0.9 mL/min: t_R = 6.4, 7.3 min.

trans-**5bo***: Column: Daicel Chiralpak AD-H; solvent: EtOH; detection: 254 nm; flow rate: 0.9 mL/min: t_R = 5.7, 8.4 min.

trans-**32c**: Column: Daicel Chiralcel AD-H; solvent: EtOH; detection: 254 nm; flow rate: 0.3 mL/min; t_R = 14.9 (major), 16.2 min (minor).

cis-**32c**: Column: Daicel Chiralcel AD-H; solvent: EtOH; detection: 254 nm; flow rate: 0.3 mL/min; t_R = 12.9 (major), 14.8 min (minor).

trans-**32b**: Column: Daicel Chiralcel AD-H; solvent: EtOH; detection: 254 nm; flow rate: 0.3 mL/min; t_R = 13.7 (major), 15.3 min (minor).

cis-**32b**: Column: Daicel Chiralcel AD-H; solvent: EtOH; detection: 254 nm; flow rate: 0.3 mL/min; t_R = 11.7 (major), 12.5 min (minor).

Supporting Information for this article is available online at http://www.thieme-connect.com/products/ejournals/journal/10.1055/s-00000084.

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