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Reactivity of Dehydroamino Acids and Dehydrodipeptides Towards *N*-Bromosuccinimide: Synthesis of β-Bromo- and β,β-Dibromodehydroamino Acid Derivatives and of Substituted 4-Imidazolidinones

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We have developed a modification of our previously reported high-yielding method for the synthesis of *N*,*N*-diacyldehydroamino acid derivatives to prepare *N*-monoprotected dehydroamino acids and dehydrodipeptides. Thus, several dehydroalanine, dehydroaminobutyric acid and dehydrophenylalanine derivatives have been prepared by treating the corresponding L-serine, L-threonine and D,L-3-phenylserine (*threo*-type) derivatives with 1 equiv. of di-*tert*-butyl dicarbonate and 4-(dimethylamino)pyridine. The reaction proceeded with the initial formation of an *O*-*tert*-butyl carbonate which, by treament with *N*,*N*,*N*′,*N*′-tetramethylguanidine, underwent β elimination to give the corresponding dehydroamino acid derivative. This two-step method can be carried out as a one-pot procedure and is stereoselective, giving only the *Z* isomer. The *N*-monoprotected dehydroamino acids were treated with *N*-bromosuccinimide and thereafter with triethylamine to afford several β,β-dibromodehydroalanines or β-bromo-, β-alkyl- or β-aryldehydroalanines. The latter were obtained as mixtures of *E* and *Z* isomers. An increased stereoselectivity towards the formation of the *Z* isomer was observed with dehydrophenylalanine and when 4-tolylsulfonyl was used as the *N*-protecting group. In the case of dehydrodipeptides, the reaction with NBS and triethylamine afforded the corresponding brominated dehydrodipeptides when the *N*-protecting group was other than 4-tolylsulfonyl. However, when the reagent was a peptide with a dehydroamino acid as the second residue and an *N*-(4-tolylsulfonyl) group the corresponding 2,2-disubstituted 1-(4-tolylsulfonyl)imidazolidin-4-ones were obtained in good-to-high yields.

Introduction

In our laboratories we have developed an efficient method for the synthesis of *N*,*N*-diacyldehydroamino acid derivatives by using di-*tert*-butyl dicarbonate (Boc_2O) and 4-(dimethylamino)pyridine (DMAP) as catalyst in dry acetonitrile at room temperature.[1,2] Owing to the high reaction yields and to the simple work-up procedures we were able to prepare these compounds in large amounts and to use them as substrates in other types of reactions to obtain new amino acids such as β-substituted alanines,[3] α-aminoglycines,[4] furanic amino acids[5] and β,β-diaryl- or heteroaryl-dehydroamino acids.[6] These dehydroamino acids were synthesized by Suzuki cross-coupling reactions of a β,β-dibromodehydroalanine[6a] or β-bromodehydrophenylalanines[6b] with several aryl- or heteroarylboronic acids. However, to prepare brominated dehydroamino acids from *N*,*N*-diacyldehydroamino acid derivatives it was always necessary to remove one of the *N*-protecting groups before the reaction with *N*-bromosuccinimide (NBS). Usually a *tert*-butyloxycarbonyl group (Boc) was cleaved by treatment with trifluoroacetic acid.[6b] Thus, it was clear to us that a modification of our method for the synthesis of *N*,*N*-diprotected dehydroamino acids allowing the preparation of *N*-monosubstituted compounds would be an advantage in the synthesis of halogenated dehydroamino acids.

The reaction sequence leading to *N*,*N*-diacyldehydroamino acids proceeds with the initial formation of a *tert*-butyl carbonate which undergoes β elimination to the final product after a *tert*-butyloxycarbonyl group has been bound to the amine function. In this case the second acyl group is the driving force for the elimination process.[1] Bearing this in mind and the fact that the β elimination of *O*-(4-tolylsulfonyl)- and *O*-dichloroacetyl-β-hydroxyamino acids to yield the corresponding dehydroamino acid derivatives with bases such as DBU, DABCO or triethylamine has already been reported,[7a–7f] we decided to use the base *N*,*N*,*N*′,*N*′-tetramethylguanidine (TMG) to induce elimination of the *tert*-butyl carbonate group from the *O*-(*tert*-butyloxycarbonyl)-β-hydroxyamino acid derivatives. The *N*-monoprotected dehydroamino acid derivatives were obtained in good yields and in the case of β-substituted β-

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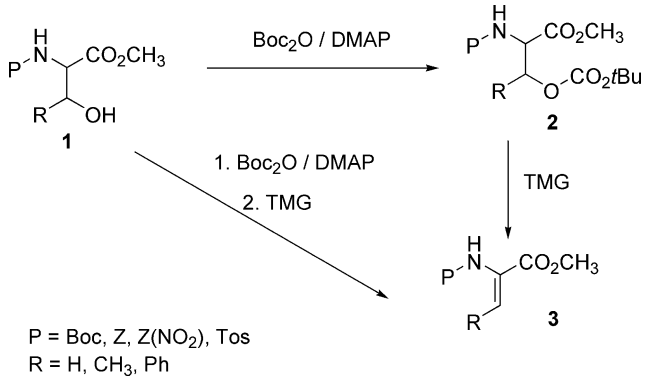
hydroxyamino acid derivatives (*threo* configuration) the only products isolated were the *Z* isomers.

Thus, we report herein the synthesis of *N*-monoprotected dehydroamino acids and dehydrodipeptides by two strategies. 1) The treatment of β-hydroxyamino acid derivatives with 2 equiv. of Boc_2O in the presence of DMAP followed by cleavage of a *tert*-butyloxycarbonyl group with TFA. 2) The synthesis of *O*-*tert*-butyl carbonates by using 1 equiv. of Boc_2O in the presence of DMAP followed by treatment with TMG.

The *N*-monoprotected dehydroamino acids and dehydrodipeptides obtained were then treated with *N*-bromosuccinimide (NBS) and triethylamine[8] to afford the corresponding β,β-dibromo- and β-bromo β-substituted dehydroalanine derivatives in good yields. It was found that when the *N*-protecting group was 4-tolylsulfonyl the dipeptides containing a dehydroamino acid in the C-terminal position gave by treatment with NBS and NEt_3, *N*-(4-tolylsulfonyl)imidazolidin-4-ones. The imidazolidinone ring is part of a series of matrix metalloproteinase inhibitors that have great potential in the treatment of a variety of diseases including arthritis and cancer.[9]

ylserine (*threo* configuration) underwent elimination to yield only the *Z* isomer. This stereoselectivity is in agreement with a *trans* E_2 elimination which was also considered by Olsen and co-workers[7d] to be the mechanism involved in the synthesis of dehydroaminobutyric acid derivatives from *O*-(4-tolylsulfonyl)threonines (*threo* type). The stereochemistry of these β-substituted dehydroamino acids was determined by NOE difference experiments by irradiating the α-NH and OCH_3 protons and observing the effect on the β-methyl and β-phenyl protons.



Scheme 1. Synthesis of the dehydroamino acid derivatives.

Results and Discussion

Several methyl esters of *N*-protected β-hydroxyamino acids [L-serine, L-threonine and D,L-3-phenylserine (*threo* type)] were treated with 1 equiv. of Boc_2O and DMAP in dry acetonitrile to give the corresponding *O*-*tert*-butyl carbonates (Scheme 1, Table 1). These compounds were then treated with a 2% solution of TMG in acetonitrile to afford the *N*-monoprotected dehydroamino acids in good yields (Scheme 1, Table 1). This two-step method can also be carried out as a one-pot procedure (Scheme 1, Table 1). In the case of β-substituted-β-hydroxyamino acids it was found that *O*-*tert*-butyloxycarbonyl-L-threonine and D,L-3-phen-

Olsen co-workers[7d] reported the synthesis of Z-*Z*-ΔAbu-OMe (**3f**) and Tos-*Z*-ΔAbu-OMe (**3h**) by the reaction of Z-Thr(*O*-Tos)-OMe and Tos-Thr(*O*-Tos)-OMe with DABCO. The reaction yields (85 and 81%, respectively) are similar to those obtained by us when Z-Thr(*O*-Boc)-OMe and Tos-Thr(*O*-Boc)-OMe were treated with TMG (84 and 91%, respectively). However, the yields reported for the synthesis of the *O*-(4-tolylsulfonyl)threonines were smaller (71 and 79%, respectively) than those obtained by us in the synthesis of *O*-(*tert*-butyloxycarbonyl)threonines (86 and 90%, respectively). Thus, the overall yields were 60 and 64%,

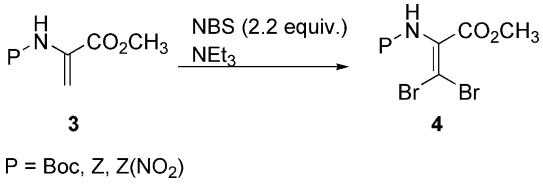
Table 1. Yields obtained in synthesis of *N*-monoprotected dehydroamino acid esters from L-serine, L-threonine and D,L-3-phenylserine (*threo* type).

Reagent	**2**	% Yield	**3**	% Yield
Boc-Ser-OMe (**1a**)	Boc-Ser(*O*-Boc)-OMe (**2a**)	80	Boc-ΔAla-OMe (**3a**)[1]	87
Boc-Ser-OMe (**1a**)	–	–	Boc-ΔAla-OMe (**3a**)[1]	82
Z-Ser-OMe (**1b**)	Z-Ser(*O*-Boc)-OMe (**2b**)	86	Z-ΔAla-OMe (**3b**)[10]	82
Z-Ser-OMe (**1b**)	–	–	Z-ΔAla-OMe (**3b**)[10]	90
Z(NO_2)-Ser-OMe (**1c**)	Z(NO_2)-Ser(*O*-Boc)-OMe (**2c**)	83	Z(NO_2)-ΔAla-OMe (**3c**)	85
Z(NO_2)-Ser-OMe (**1c**)	–	–	Z(NO_2)-ΔAla-OMe (**3c**)	90
Tos-Ser-OMe (**1d**)	Tos-Ser(*O*-Boc)-OMe (**2d**)	81	Tos-ΔAla-OMe (**3d**)	–
Tos-Ser-OMe (**1d**)	–	–	Tos-ΔAla-OMe (**3d**)	65
Boc-Thr-OMe (**1e**)	Boc-Thr(*O*-Boc)-OMe (**2e**)	87	Boc-*Z*-ΔAbu-OMe (**3e**)[1]	98
Boc-Thr-OMe (**1e**)	–	–	Boc-*Z*-ΔAbu-OMe (**3e**)[1]	82
Z-Thr-OMe (**1f**)	Z-Thr(*O*-Boc)-OMe (**2f**)	86	Z-*Z*-ΔAbu-OMe (**3f**)[1]	84
Z-Thr-OMe (**1f**)	–	–	Z-*Z*-ΔAbu-OMe (**3f**)[1]	83
Z(NO_2)-Thr-OMe (**1g**)	Z(NO_2)-Thr(*O*-Boc)-OMe (**2g**)	89	Z(NO_2)-*Z*-ΔAbu-OMe (**3g**)[1]	95
Z(NO_2)-Thr-OMe (**1g**)	–	–	Z(NO_2)-*Z*-ΔAbu-OMe (**3g**)[1]	91
Tos-Thr-OMe (**1h**)	Tos-Thr(*O*-Boc)-OMe (**2h**)	90	Tos-*Z*-ΔAbu-OMe (**3h**)	91
Tos-Thr-OMe (**1h**)	–	–	Tos-*Z*-ΔAbu-OMe (**3h**)	86
Boc-Phe(β-OH)-OMe (**1i**)	Boc-Phe(β-*O*-Boc)-OMe (**2i**)	82	Boc-*Z*-ΔPhe-OMe (**3i**)[3b]	88
Boc-Phe(β-OH)-OMe (**1i**)	–	–	Boc-*Z*-ΔPhe-OMe (**3i**)[3b]	81
Tos-Phe(β-OH)-OMe (**1j**)	Tos-Phe(β-*O*-Boc)-OMe (**2j**)	73	Tos-*Z*-ΔPhe-OMe (**3j**)	–
Tos-Phe(β-OH)-OMe (**1j**)	–	–	Tos-*Z*-ΔPhe-OMe (**3j**)	81

respectively, by using the Tos-Cl/pyridine/DABCO method and 72 and 82% by using our Boc_2O/DMAP/TMG procedure. These latter results are similar to those reported by us using 2.2 equiv. of Boc_2O in the presence of DMAP followed by treatment with TFA (72 and 74%, respectively).[1]

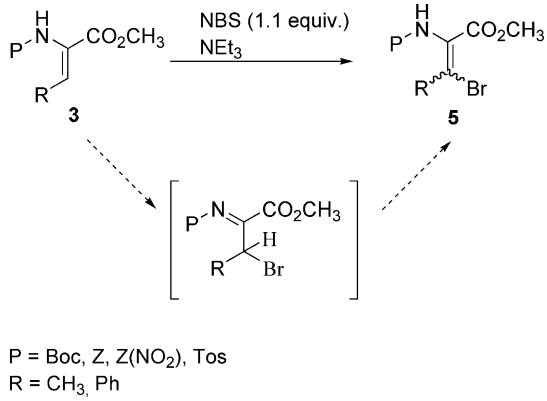
When the reagent was Tos-Ser-OMe (**1d**) we were able to prepare the corresponding *tert*-butyl carbonate in good yield (81%). This compound, when treated with TMG, gave immediately the corresponding dehydroalanine derivative (**3d**), however, the product was found to be highly unstable in the presence of base giving 4-toluenesulfonamide.

The *N*-monoprotected dehydroamino acids were treated with 2.2 equiv. of NBS and then with NEt_3 to give β,β-dibromodehydroalanines in yields of between 52 and 86% depending on the *N*-protecting group (Scheme 2, Table 2). Compound **4a** had already been prepared by us and used together with aryl- and heteroarylboronic acids in Suzuki cross-coupling reactions to synthesize aryl- or heteroaryldehydroalanine derivatives.[6a,11]



Scheme 2. Synthesis of β,β-dibromodehydroalanines.

The *Z* isomers of dehydroaminobutyric acid and dehydrophenylalanine derivatives were treated with 1.1 equiv. of NBS and NEt_3 to give the corresponding β-substituted β-bromodehydroalanine (compounds **5e**–**h** and **6i**,**j**, respectively) in yields ranging from 78 to 97% (Scheme 3, Table 2). According to the mechanism proposed[8] for this reaction the dehydroamino acid reacts with NBS to give a β-bromo β-imino ester which upon treatment with NEt_3 yields the β-bromo enamine. In all cases except for Tos-ΔPhe(β-Br)-OMe (**6j**), a mixture of *E* and *Z* isomers were obtained which could be separated by column chromatography. It was found that there is an increase in stereoselectivity towards the *Z* isomer with the dehydrophenylalanine derivative. This result is in agreement with those obtained by Nunami and co-workers[12a] who reported a 1:2 *E*/*Z* ratio for the bromination of the methyl ester of *N*-formyl-Z-dehydrophenylalanine and a 1:1 *E*/*Z* ratio for the bromination of the methyl ester of *N*-formyl-Z-dehydroaminobutyric acid. An increase in *Z* stereoselectivity was also found when the 4-tolylsulfonyl group was used as the *N*-protecting group (**5h**). In the case of compound **6j**, which has an *N*-(4-tolylsulfonyl) group and is a derivative of dehydrophenylalanine, only the *Z* isomer was obtained.



Scheme 3. Synthesis of β-bromo-β-substituted dehydroamino acids.

The stereochemistry of the β-bromodehydroamino acids was determined by NOE difference experiments by irradiating the α-NH and OCH_3 protons and observing the effect on the β-methyl and β-phenyl protons. As reported by other authors,[12a,12b] we found that for compounds with an alkyl substituent at the β position (**5e**–**g**) the chemical shift of the γ-CH_3 protons of the *E* isomers is observed at a higher field relative to that of the corresponding *Z* isomer (Table 3). However, in the case of Tos-ΔAbu(β-Br)-OMe (**5h**), the chemical shift of the γ-CH_3 protons of the *E* isomer appears at a lower field (δ = 2.63 ppm in $CDCl_3$) which is probably due to the proximity of the 4-tolylsulfonyl group.

Several dehydrodipeptides were prepared from the corresponding dipeptides containing L-serine, L-threonine and D,L-3-phenylserine by using 3.3 equiv. of Boc_2O in the presence of DMAP followed by cleavage of the Boc groups with TFA (Scheme 4, Table 4).

The *O*-*tert*-butyl carbonates of dipeptides containing β-hydroxyamino acids were obtained by using 1 equiv. of Boc_2O in the presence of DMAP. These compounds in the presence of TMG afforded the corresponding dehydrodipeptides in good yields (Scheme 5, Table 5).

Compound **9f** was obtained in a 77% yield by using Boc_2O/DMAP followed by TMG which is slightly less than that obtained by using 3.3 equiv. of Boc_2O/DMAP and

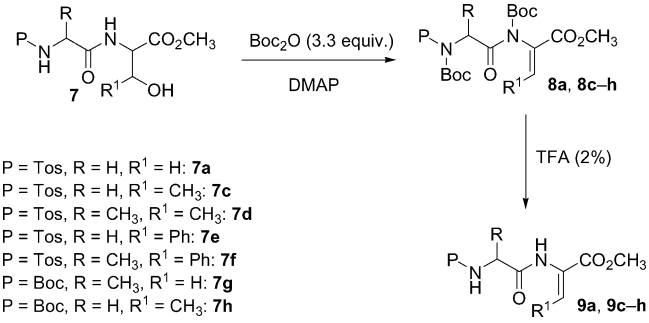
Table 2. Results obtained in the synthesis of β-brominated dehydroamino acid derivatives.

Reagent	Product	% Yield	*E*/*Z*
Boc-ΔAla-OMe (**3a**)	Boc-ΔAla(β,β-Br)-OMe (**4**)[6a]	52[6a]	–
Z-ΔAla-OMe (**3b**)	Z-ΔAla(β,β-Br)-OMe (**4b**)	86	–
Z(NO_2)-ΔAla-OMe (**3c**)	Z(NO_2)-ΔAla(β,β-Br)-OMe (**4c**)	75	–
Boc-ΔAbu-OMe (**3e**)	Boc-ΔAbu(β-Br)-OMe (**5e**)[13]	92[13]	1:1[13]
Z-ΔAbu-OMe (**3f**)	Z-ΔAbu(β-Br)-OMe (**5f**)	89	1:1
Z(NO_2)-ΔAbu-OMe (**3g**)	Z(NO_2)-ΔAbu(β-Br)-OMe (**5g**)	80	1:1
Tos-ΔAbu-OMe (**3h**)	Tos-ΔAbu(β-Br)-OMe (**5h**)	94	1:9
Boc-ΔPhe-OMe (**3i**)	Boc-ΔPhe(β-Br)-OMe (**6i**)[6b]	97[6b]	1:2[6b]
Tos-ΔPhe-OMe **3j**)	Tos-*Z*-ΔPhe(β-Br)-OMe (**6j**)	78	only *Z*

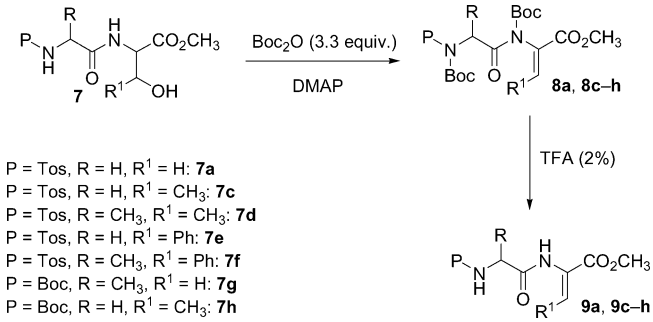
Table 3. Chemical shifts of the γ-CH_3 protons of β-bromodehydroaminobutyric acid derivatives in $CDCl_3$.

(*Z*)-**5**	δ(γ-CH_3) [ppm]	(*E*)-**5**	δ(γ-CH_3) [ppm]
Boc-ΔAbu(β-Br)-OMe [(*Z*)-**5e**]	2.52	Boc-ΔAbu(β-Br)-OMe [(*E*)-**5e**]	2.41
Z-ΔAbu(β-Br)-OMe [(*Z*)-**5f**]	2.56	Z-ΔAbu(β-Br)-OMe [(*E*)-**5f**]	2.41
Z(NO_2)-ΔAbu(β-Br)-OMe [(*Z*)-**5g**]	2.59	Z(NO_2)-ΔAbu(β-Br)-OMe [(*E*)-**5g**]	2.44
Tos-ΔAbu(β-Br)-OMe [(*Z*)-**5h**]	2.54	Tos-ΔAbu(β-Br)-OMe [(*E*)-**5h**]	2.63

TFA (82%). However, the overall yield obtained in the synthesis of compound **9h** by using Boc_2O/DMAP followed by TMG is higher (84%) than that obtained by using 3.3 equiv. of Boc_2O/DMAP and TFA (71%). When compound **7b** was treated with 3.3 equiv. of Boc_2O in the presence of DMAP it was found that the reagent was consumed but failed to give the corresponding Tos-Ala(*N*-Boc)-ΔAla(*N*-Boc)-OMe and thus it was impossible to prepare compound **9b** by this route. The latter was synthesized in high yield (93%) by treatment of **7b** with Boc_2O/DMAP and TMG.



Scheme 4. Synthesis of dehydrodipeptides using Boc_2O/DMAP followed by treatment with TFA.



Scheme 5. Synthesis of dehydrodipeptides using Boc_2O/DMAP followed by treatment with TMG.

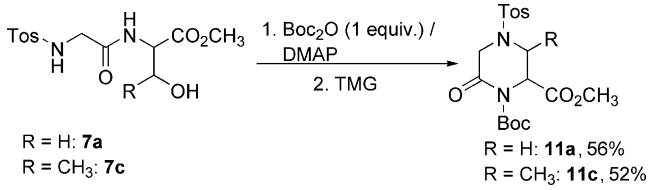
In the case of *N*-(4-tolylsulfonyl)dipeptides (compounds **7a** and **7c**) the reaction with 1 equiv. of Boc_2O/DMAP and TMG gave the corresponding piperazine derivatives (Scheme 6). In the case of piperazine **11c**, the ^{1}H NMR analysis showed that only one stereoisomer was formed. This cyclization results from the nucleophilic attack of the sulfonamide nitrogen on the β-carbon atom of the β-hydroxyamino acid derivative. It was possible to prepare the dehydrodipeptides **9a** and **9c** by using Boc_2O (3.3 equiv.)/DMAP followed by treatment with TFA (Table 4).

Table 4. Yields obtained in the synthesis of dehydrodipeptide derivatives on treatment of the corresponding dipeptides with Boc_2O/DMAP followed by TFA.

Reagent	**8**	% Yield	**9**	% Yield
7a	Tos-Gly(*N*-Boc)-ΔAla(*N*-Boc)-OMe (**8a**)[3a]	96	Tos-Gly-ΔAla-OMe (**9a**)	96
7c	Tos-Gly(*N*-Boc)-*Z*-ΔAbu(*N*-Boc)-OMe (**8c**)	91	Tos-Gly-*Z*-ΔAbu-OMe (**9c**)	96
7d	Tos-Ala(*N*-Boc)-*Z*-ΔAbu(*N*-Boc)-OMe (**8d**)	52	Tos-Ala-*Z*-ΔAbu-OMe (**9d**)	47
7e	Tos-Gly(*N*-Boc)-*Z*-ΔPhe(*N*-Boc)-OMe (**8e**)	96	Tos-Gly-*Z*-ΔPhe-OMe (**9e**)	92
7f	Tos-Ala(*N*-Boc)-*Z*-ΔPhe(*N*-Boc)-OMe (**8f**)	94	Tos-Ala-*Z*-ΔPhe-OMe (**9f**)	87
7g	Boc-Ala(*N*-Boc)-ΔAla(*N*-Boc)-OMe (**8g**)[1]	91[1]	Boc-Ala-ΔAla-OMe (**9g**)	92
7h	Boc-Gly(*N*-Boc)-*Z*-ΔAbu(*N*-Boc)-OMe (**8h**)	82	Boc-Gly-*Z*-ΔAbu-OMe (**9h**)	87

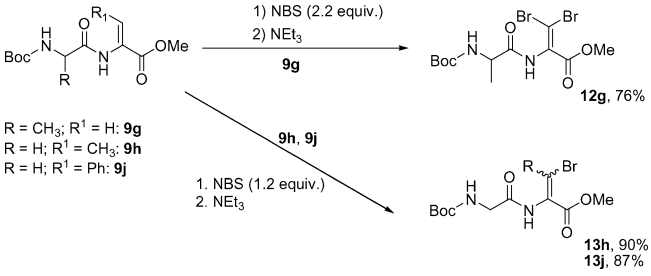
Table 5. Yields obtained in the synthesis of dehydrodipeptides upon treatment of dipeptides with Boc_2O/DMAP followed by TMG.

Reagent	**10**	% Yield	**9**	% Yield
7b	Tos-Ala-Ser(*O*-Boc)-OMe (**10b**)	85	Tos-Ala-ΔAla-OMe (**9b**)	–
7b	Tos-Ala-Ser(*O*-Boc)-OMe (**10b**)	–	Tos-Ala-ΔAla-OMe (**9b**)	93
7f	Tos-Ala-Phe(β-*O*-Boc)-OMe (**10f**)	–	Tos-Ala-ΔPhe-OMe (**9f**)	77
7h	Boc-Gly-Thr(*O*-Boc)-OMe (**10h**)	79	Boc-Gly-*Z*-ΔAbu-OMe (**9h**)	92
7h	Boc-Gly-Thr(*O*-Boc)-OMe (**10h**)	–	Boc-Gly-*Z*-ΔAbu-OMe (**9h**)	84
7i	Boc-Gly-Ser(*O*-Boc)-OMe (**10i**)	67	Boc-Gly-ΔAla-OMe (**9i**)	65
7i	Boc-Gly-Ser(*O*-Boc)-OMe (**10i**)	–	Boc-Gly-ΔAla-OMe (**9i**)	59
7j	–	–	Boc-Gly-*Z*-ΔPhe-OMe (**9j**)	82
7l	–	–	Z-Gly-ΔAla-OMe (**9l**)	61



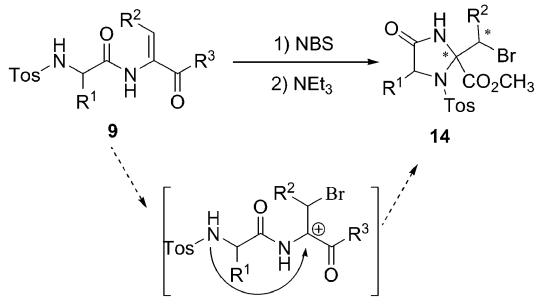
Scheme 6. Reaction of Tos-Gly-L-Ser-OMe and Tos-Gly-L-Thr-OMe with Boc_2O (1 equiv.)/DMAP followed by TMG.

In order to prepare brominated peptides, the dehydrodipeptides were treated with NBS and then with NEt_3. It was found that when the *N*-protecting group was other than 4-tolylsulfonyl the corresponding β,β-dibromodehydrodipeptide and β-bromo-β-substituted dehydrodipeptide derivatives were obtained (Scheme 7, compounds **12g**, **13h** and **13j**). A 1:1 *E*/*Z* mixture was formed in the case of the β-bromo β-substituted dehydrodipeptides. However, when the *N*-protecting group was 4-tolylsulfonyl the reaction of dehydrodipeptides with NBS afforded the 2,2-disubstituted 1-(4-tolylsulfonyl)imidazolidin-4-one in good-to-high yields (Scheme 8, compounds **14a**–**f**). We believe that the initial step in the formation of these compounds is the bromination of the dehydroamino acid residue by NBS. This is followed by cyclization which occurs by nucleophilic attack of the nitrogen atom of the sulfonamide moiety on the α-carbon atom of the second amino acid residue. The results show that the presence of the 4-tolylsulfonyl group is essential for the intramolecular cyclization. Also, NOESY experiments performed on Boc-Gly-ΔAbu-OMe (**9c**) showed a correlation between the γ-CH_3 protons of the ΔAbu residue and the aromatic protons of the 4-tolylsulfonyl group. With Boc-Gly-ΔAbu-OMe (**9h**) it is not possible to observe a similar correlation with the CH_3 protons of the Boc group. These results suggest that the NH proton of the 4-tolylsulfonylamide moiety in compound **9c** is closer to the ΔAbu residue than that of the *tert*-butyloxycarbonylamide in compound **9h**.



Scheme 7. Synthesis of β-bromodehydrodipeptides.

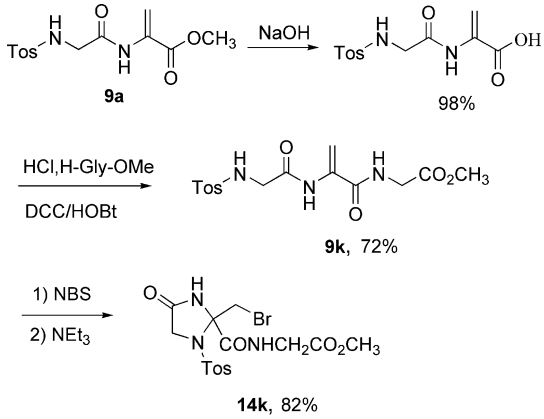
In the synthesis of compounds **14a**–**f** at least one stereocentre is generated which leads to the possibility of obtaining two diastereomers for compounds **14b**, **14c** and **14e** and four diastereomers in the case of compounds **14d** and **14f**. The reaction of compound **9b** with NBS and NEt_3 gave as expected compound **14b** as a mixture of two diastereomers each one presenting a quartet in the ^1H NMR spectrum (δ = 4.36 and 4.07 ppm) corresponding to the C5–CH_3 resonance. The same reaction with the dehydrophenylalanine derivatives **9e** and **9f** gave compounds **14e** and **14f** as a mixture of two and four diastereomers, respectively. The ^1H NMR spectra of these reaction mixtures showed two singlets at δ = 6.37 and 6.18 ppm for compound **14e** and four singlets at 6.64, 6.45, 6.16 and 6.13 ppm for compound **14f** corresponding to the C*H*BrPh resonances. The dehydroaminobutyric acid derivatives behaved differently. Thus, the reaction of compound **9c** gave only one diastereomer of compound **14c** although two stereocentres were generated. In the case of compound **14d**, four diastereomers were anticipated, however, only two diastereomers were formed (1:1), each one presenting a quartet (5.51 and 5.22 ppm) corresponding to a C*H*BrCH_3 resonance and a singlet (3.57 and 3.39 ppm) corresponding to a OCH_3 resonance. These results suggest stereoselectivity in the cyclization of the dehydroaminobutyric acid derivatives.



R^1	R^2	Reactant	Product	% Yield
H	H	**9a**	**14a**	92
CH_3	H	**9b**	**14b**	88
H	CH_3	**9c**	**14c**	94
CH_3	CH_3	**9d**	**14d**	74
H	Ph	**9e**	**14e**	86
CH_3	Ph	**9f**	**14f**	91

Scheme 8. Yields obtained in the synthesis of imidazolidin-4-ones from dehydrodipeptides.

In order to test this reaction with larger peptides, a tripeptide (compound **9k**) was synthesized in a 71% overall yield by saponification of the dipeptide **9a** (98%) followed by coupling with the methyl ester of glycine using the DCC/



Scheme 9. Synthesis of imidazolidin-4-one (**14k**) from a dehydrotripeptide derivative.

HOBt method (72%). This compound was then treated with NBS and NEt_3 to give the corresponding imidazolidinone **14k** in 82% yield (Scheme 9) thus showing that this reaction can also be applied to tripeptides containing a β-dehydroamino acid as the second residue and an *N*-(4-tolylsulfonyl) group.

Conclusions

Several *N*-monoprotected dehydroamino acids and dehydrodipeptides have been prepared by a modification of our previously described method for the synthesis of *N*,*N*-diacyldehydroamino acid derivatives. This modification involves treating the β-hydroxyamino acid with 1 equiv. of Boc_2O in the presence of DMAP to give the corresponding *tert*-butyl carbonates which undergo β elimination in the presence of TMG to give the dehydroamino acid derivatives. With threonine and β-hydroxyphenylserine the reaction is stereoselective giving only the Z isomer. This method for the preparation of *N*-monoprotected dehydroamino acid derivatives has advantages, namely good yields and the possibility of performing these reactions in a one-pot procedure. The compounds prepared were treated with NBS followed by NEt_3 to give the corresponding β,β-dibromodehydroalanines and β-bromo β-substituted dehydroamino acids. In the case of dehydroaminobutyric acid and dehydrophenylalanine the corresponding brominated derivatives were obtained as mixtures of *Z* and *E* isomers. An increased Z stereoselectivity was observed with dehydrophenylalanine and when 4-tolylsulfonyl was used as the *N*-protecting group. Treatment of *N*-(*tert*-butyloxycarbonyl)dehydrodipeptides with NBS and NEt_3 afforded the corresponding brominated dehydrodipeptides. However, when the reagent was a peptide with a β-dehydroamino acid as the second residue and an *N*-(4-tolylsulfonyl) group the corresponding 1-(4-tolylsulfonyl)imidazolidin-4-ones were obtained in good-to-high yields.

Experimental Section

General Methods: Melting points were determined with a Gallenkamp apparatus and are uncorrected. ^1H and ^{13}C NMR spectra were recorded on a Varian Unity Plus spectrometer at 300 and 75.4 MHz, respectively. ^1H–^1H spin-spin decoupling and DEPT θ 45° were used. Chemical shifts are given in ppm and coupling constants in Hz. MS and HRMS data were recorded by the mass spectrometry service of the University of Vigo, Spain. Elemental analysis was performed on a LECO CHNS 932 elemental analyser. Reactions were monitored by thin-layer chromatography (TLC). Column chromatography was performed on Macherey–Nagel silica gel 230–400 mesh. Petroleum ether refers to the boiling range 40–60 °C. When a solvent gradient was used, the polarity was increased from neat petroleum ether to mixtures of diethyl ether/petroleum ether by increasing in steps of 10% diethyl ether each time until the product was isolated.

Synthesis of the Methyl Esters of *N*-Protected β-Hydroxyamino Acids 1a–j: The synthesis of these compounds has been described elsewhere.[1]

Synthesis of the *N*-Acyl-*O*-(*tert*-butyloxycarbonyl)hydroxyamino Acid Esters 2a–j

Boc-Ser(*O*-Boc)-OMe (2a): DMAP (0.1 equiv.) was added to a solution of Boc-L-Ser-OMe (5 mmol, 1.10 g) in dry acetonitrile (1 mol dm^{-3}) followed by di-*tert*-butyl dicarbonate (1.0 equiv.) under rapid stirring at room temperature. The reaction was monitored by TLC (diethyl ether/*n*-hexane, 1:1) until all the reactant had been consumed. Evaporation at reduced pressure gave a residue that was partitioned between diethyl ether (100 mL) and $KHSO_4$ (30 mL, 1 mol dm^{-3}). The organic phase was thoroughly washed with $KHSO_4$ (1 mol dm^{-3}), $NaHO_3$ (1 mol dm^{-3}) and brine (2 × 30 mL, each), and dried with $MgSO_4$. Removal of the solvent afforded pure **2a** (1.28 g, 80%). M.p. 101.0–102.0 °C (from ethyl acetate/*n*-hexane). ^1H NMR ($CDCl_3$): δ = 5.35 (br. d, *J* = 8.1 Hz, 1 H, NH), 4.57–4.52 (m, 1 H, αCH), 4.48 (dd, *J* = 3.6, *J* = 11.1 Hz, 1 H, βCH_2), 4.30 (dd, *J* = 3.6, *J* = 11.1 Hz, 1 H, βCH_2), 3.77 (s, 3 H, CH_3 CO_2Me), 1.47 (s, 9 H, CH_3 Boc), 1.45 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.13 (C=O), 155.13 (C=O), 152.98 (C=O), 82.77 [$C(CH_3)_3$], 80.22 [$C(CH_3)_3$], 66.34 (βCH_2), 52.95 (αCH), 52.71 (OCH_3), 28.24 [$C(CH_3)_3$], 27.63 [$C(CH_3)_3$] ppm. $C_{14}H_{25}NO_7$ (319.35): calcd. C 52.65, H 7.89, N 4.39; found C 52.51, H 7.94, N 4.48.

Z-Ser(*O*-Boc)-OMe (2b): The same procedure described for the preparation of **2a** was followed substituting Z-L-Ser-OMe (5 mmol, 1.27 g) for Boc-L-Ser-OMe to give **2b** (1.52 g, 86%). M.p. 52.0–53.0 °C (from ethyl acetate/*n*-hexane). ^1H NMR ($CDCl_3$): δ = 7.36 (s, 5 H, ArH), 5.64 (br. d, *J* = 8.4 Hz, 1 H, NH), 5.13 (s, 2 H, CH_2 Z), 4.65–4.61 (m, 1 H, αCH), 4.44 (dd, *J* = 3.6, *J* = 11.1 Hz, 1 H, βCH_2), 4.34 (dd, *J* = 3.6, *J* = 11.1 Hz, 1 H, βCH_2), 3.78 (s, 3 H, CH_3 CO_2Me), 1.47 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.74 (C=O), 155.71 (C=O), 152.93 (C=O), 136.01 (C), 128.50 (CH), 128.19 (CH), 128.08 (CH), 82.88 [$C(CH_3)_3$], 67.15 (CH_2), 66.10 (βCH_2), 53.39 (αCH), 52.83 (OCH_3), 27.59 [$C(CH_3)_3$] ppm. $C_{17}H_{23}NO_7$ (353.37): calcd. C 57.78, H 6.56, N 3.96; found C 58.18, H 6.58, N 4.13.

Z(NO_2)-Ser(*O*-Boc)-OMe (2c): The same procedure described for the preparation of **2a** was followed substituting Z(NO_2)-L-Ser-OMe (5 mmol, 1.49 g) for Boc-L-Ser-OMe to give **2c** (1.65g, 83%) as an oil. ^1H NMR ($CDCl_3$): δ = 8.22 (d, *J* = 8.7 Hz, 2 H, ArH), 7.51 (d, *J* = 8.7 Hz, 2 H, ArH), 5.75 (br. d, *J* = 8.1 Hz, 1 H, NH), 5.22 [s, 2 H, CH_2 Z(NO_2)], 4.62–4.57 (m, 1 H, αCH), 4.49 (dd, *J* = 3.9, *J* = 11.1 Hz, 1 H, βCH_2), 4.36 (dd, *J* = 3.9, *J* = 11.1 Hz, 1 H, βCH_2), 3.79 (s, 3 H, CH_3 CO_2Me), 1.46 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.55 (C=O), 155.27 (C=O), 152.93 (C=O), 147.60 (C), 143.49 (C), 128.04 (CH), 123.71 (CH), 83.05 [$C(CH_3)_3$], 65.93 (βCH_2), 65.52 (CH_2), 53.52 (αCH), 52.94 (OCH_3), 27.57 [$C(CH_3)_3$] ppm. $C_{17}H_{22}N_2O_9$ (398.37): calcd. C 51.26, H 5.57, N 7.03; found C 51.60, H 5.40, N 7.00.

Tos-Ser(*O*-Boc)-OMe (2d): The same procedure described for the preparation of **2a** was followed substituting Tos-L-Ser-OMe (5 mmol, 1.37 g) for Boc-L-Ser-OMe to give **2d** (1.51 g, 81%). M.p. 67.5–68.5 °C (from diethyl ether/*n*-hexane). ^1H NMR ($CDCl_3$): δ = 7.74 (d, *J* = 8.1 Hz, 2 H, ArH), 7.30 (d, *J* = 8.1 Hz, 2 H, ArH), 5.41 (br. d, *J* = 8.1 Hz, 1 H, NH), 4.41–4.35 (m, 1 H, βCH_2), 4.25–4.21 (m, 2 H, βCH_2 + αCH), 3.60 (s, 3 H, CH_3 CO_2Me), 2.43 (s, 3 H, CH_3 Tos), 1.46 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.09 (C=O), 152.72 (C=O), 143.78 (C), 136.73 (C), 129.06 (CH), 127.12 (CH), 82.99 [$C(CH_3)_3$], 66.62 (βCH_2), 54.81 (αCH), 52.97 (OCH_3), 27.60 [$C(CH_3)_3$], 21.49 (CH_3 Tos) ppm. $C_{16}H_{23}NO_7S$ (373.42): calcd. C 51.46, H 6.21, N 3.75, S 8.59; found C 51.31, H 6.06, N 3.97, S 8.62.

Boc-Thr(*O*-Boc)-OMe (2e): The same procedure described for the preparation of **2a** was followed substituting Boc-L-Thr-OMe (5 mmol, 1.17 g) for Boc-L-Ser-OMe to give **2e** (1.45 g, 87%) as an oil. ^{1}H NMR ($CDCl_3$): δ = 5.28–5.19 (m, 2 H, βCH + NH), 4.40 (dd, J = 2.1, J = 9.9 Hz, 1 H, αCH), 3.73 (s, 3 H, CH_3 CO_2Me), 1.44 (s, 9 H, CH_3 Boc), 1.41 (s, 9 H, CH_3 Boc), 1.32 (d, J = 6.3 Hz, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.59 (C=O), 156.00 (C=O), 152.39 (C=O), 82.54 [$C(CH_3)_3$], 80.04 [$C(CH_3)_3$], 73.05 (βCH), 56.96 (αCH), 52.51 (OCH_3), 28.20 [C(CH_3)$_3$], 27.60 [C(CH_3)$_3$], 17.00 (γCH_3) ppm. $C_{15}H_{27}NO_7$ (333.38): calcd. C 54.04, H 8.16, N 4.20; found C 54.22, H 7.83, N 4.27.

Z-Thr(*O*-Boc)-OMe (2f): The same procedure described for the preparation of **2a** was followed substituting Z-L-Thr-OMe (5 mmol, 1.34 g) for Boc-L-Ser-OMe to give **2f** (1.58 g, 86%) as an oil that solidified on standing. M.p. 65.5–66.5 °C. ^{1}H NMR ($CDCl_3$): δ = 7.30 (s, 5 H, ArH), 5.53 (br. d, J = 9.9 Hz, 1 H, NH), 5.30–5.23 (m, 1 H, βCH), 5.14 (s, 2 H, CH_2 Z), 4.48 (dd, J = 2.4, J = 9.8 Hz, 1 H, αCH), 3.75 (s, 3 H, CH_3 CO_2Me), 1.45 (s, 9 H, CH_3 Boc), 1.34 (d, J = 6.3 Hz, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.28 (C=O), 156.47 (C=O), 152.34 (C=O), 136.07 (C), 128.49 (CH), 128.16 (CH), 127.97 (CH), 82.66 [$C(CH_3)_3$], 72.80 (βCH), 67.18 (CH_2), 57.50 (αCH), 52.65 (OCH_3), 27.58 [C(CH_3)$_3$], 17.06 (γCH_3) ppm. $C_{18}H_{25}NO_7$ (367.40): calcd. C 58.85, H 6.86, N 3.81; found C 59.05, H 6.80, N 4.05.

Z(NO_2)-Thr(*O*-Boc)-OMe (2g): The same procedure described for the preparation of **2a** was followed substituting Z(NO_2)-L-Thr-OMe (5 mmol, 1.56 g) for Boc-L-Ser-OMe to give **2g** (1.84 g, 89%) as an oil. ^{1}H NMR ($CDCl_3$): δ = 8.23 (d, J = 8.7 Hz, 2 H, ArH), 7.52 (d, J = 8.7 Hz, 2 H, ArH), 5.62 (br. d, J = 9.6 Hz, 1 H, NH), 5.32–5.25 (m, 1 H, βCH), 5.23 [s, 2 H, CH_2 Z(NO_2)], 4.46 (dd, J = 2.4, J = 9.6 Hz, 1 H, αCH), 3.76 (s, 3 H, CH_3 CO_2Me), 1.46 (s, 9 H, CH_3 Boc), 1.35 (d, J = 6.3 Hz, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.13 (C=O), 156.04 (C=O), 152.28 (C=O), 147.62 (C), 143.52 (C), 127.98 (CH), 123.75 (CH), 82.87 [$C(CH_3)_3$], 72.68 (βCH), 65.61 (CH_2), 57.61 (αCH), 52.77 (OCH_3), 27.59 [C(CH_3)$_3$], 17.10 (γCH_3) ppm. $C_{18}H_{24}N_2O_9$ (412.39): calcd. C 52.43, H 5.87, N 6.79; found C 52.59, H 5.93, N 6.89.

Tos-Thr(*O*-Boc)-OMe (2h): The same procedure described for the preparation of **2a** was followed substituting Tos-L-Thr-OMe (5 mmol, 1.44 g) for Boc-L-Ser-OMe to give **2h** (1.74 g, 90%) as an oil. ^{1}H NMR ($CDCl_3$): δ = 7.70 (d, J = 8.7 Hz, 2 H, ArH), 7.27 (d, J = 8.7 Hz, 2 H, ArH), 5.33 (br. d, J = 7.8 Hz, 1 H, NH), 5.16–5.08 (m, 1 H, CH), 3.97 (br. d, J = 5.7 Hz, 1 H, CH), 3.49 (s, 3 H, CH_3 CO_2Me), 2.41 (s, 3 H, CH_3 Tos), 1.43 (s, 9 H, CH_3 Boc), 1.34 (d, J = 6.3 Hz, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.49 (C=O), 152.32 (C=O), 143.69 (C), 136.68 (C), 129.56 (CH), 127.15 (CH), 82.77 [$C(CH_3)_3$], 72.59 (CH), 59.62 (CH), 52.67 (OCH_3), 27.55 [C(CH_3)$_3$], 21.48 (CH_3), 17.00 (γCH_3) ppm. $C_{17}H_{25}NO_7S$ (387.45): calcd. C 52.70, H 6.50, N 3.62, S 8.28; found C 53.26, H 6.67, N 3.67, S 8.15.

Boc-Phe(β-*O*-Boc)-OMe (2i): The same procedure described for the preparation of **2a** was followed substituting Boc-D,L-Phe(β-OH)-OMe (5 mmol, 1.48 g) for Boc-L-Ser-OMe to give **2i** (1.62 g, 82%). M.p. 85.0–86.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.37–7.33 (m, 5 H, ArH), 6.08 (d, J = 3.0 Hz, 1 H, βCH), 5.32 (d, J = 9.9 Hz, 1 H, NH), 4.69 (dd, J = 3.0, J = 9.9 Hz, 1 H, αCH), 3.76 (s, 3 H, CH_3 CO_2Me), 1.45 (s, 9 H, CH_3 Boc), 1.32 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.16 (C=O), 155.01 (C=O), 152.19 (C=O), 136.17 (C), 128.39 (CH), 128.31 (CH), 126.08 (CH), 83.05 [$C(CH_3)_3$], 82.99 [$C(CH_3)_3$], 79.96 (βCH), 57.89 (αCH), 52.66 (OCH_3), 28.09 [C(CH_3)$_3$], 27.57 [C(CH_3)$_3$] ppm. $C_{20}H_{29}NO_7$ (395.45): calcd. C 60.75, H 7.39, N 3.54; found C 60.63, H 7.31, N 3.62.

Tos-Phe(β-*O*-Boc)-OMe (2j): The same procedure described for the preparation of **2a** was followed substituting Tos-D,L-Phe(β-OH)-OMe (5 mmol, 1.75 g) for Boc-L-Ser-OMe to give **2j** (1.64g, 73%). M.p. 119.5–120.5 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.46 (d, J = 8.1 Hz, 2 H, ArH), 7.27 (s, 5 H, ArH), 7.13 (d, J = 8.1 Hz, 2 H, ArH), 5.95 (d, J = 3.3 Hz, 1 H, βCH), 5.36 (d, J = 10.2 Hz, 1 H, NH), 4.26 (dd, J = 10.2, J = 3.3 Hz, 1 H, αCH), 3.57 (s, 3 H, CH_3 CO_2Me), 2.38 (s, 3 H, CH_3 Tos), 1.44 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.34 (C=O), 152.13 (C=O), 143.35 (C), 136.61 (C), 135.43 (C), 129.40 (CH), 128.48 (CH), 128.42 (CH), 126.97 (CH), 126.34 (CH), 83.26 [$C(CH_3)_3$], 77.00 (βCH_2), 60.32 (αCH), 52.81 (OCH_3), 27.57 [C(CH_3)$_3$], 21.45 (CH_3 Tos) ppm. $C_{22}H_{27}NO_7S$ (449.52): calcd. C 58.78, H 6.05, N 3.12, S 7.13; found C 58.86, H 6.12, N 3.21, S 7.13.

Synthesis of *N*-Acyldehydroamino Acid Esters 3a–c,e–i from *N*-Acyl-*O*-(*tert*-butyloxycarbonyl)hydroxyamino Acid Esters

Boc-ΔAla-OMe (3a): TMG (2% in volume) was added to a solution of Boc-L-Ser(*O*-Boc)-OMe (1 mmol, 0.320 g) in acetonitrile (1 mol dm^{-3}). The reaction was monitored by TLC (diethyl ether/*n*-hexane, 1:1) until all the reactant had been consumed. Evaporation at reduced pressure gave a residue that was partitioned between diethyl ether (100 mL) and $KHSO_4$ (30 mL, 1 mol dm^{-3}). The organic phase was thoroughly washed with $KHSO_4$ (1 mol dm^{-3}), $NaHCO_3$ (1 mol dm^{-3}) and saturated brine (2 × 30 mL, each), and dried with $MgSO_4$. Removal of the solvent afforded pure **3a** (0.175 g, 87%).[1]

Z-ΔAla-OMe (3b): The same procedure described for the preparation of **3a** was followed substituting Z-L-Ser(*O*-Boc)-OMe (1 mmol, 0.353 g) for Boc-L-Ser(*O*-Boc)-OMe to give **3b** (0.193 mg, 82%) as an oil.[10] ^{1}H NMR ($CDCl_3$): δ = 7.40–7.37 (m, 5 H, ArH), 7.26 (br. s, 1 H, NH), 6.26 (s, 1 H, βCH_2), 5.80 (s, 1 H, βCH_2), 5.18 (s, 2 H, CH_2 Z), 3.84 (s, 3 H, CH_3 CO_2Me) ppm.

Z(NO_2)-ΔAla-OMe (3c): The same procedure described for the preparation of **3a** was followed substituting Z(NO_2)-L-Ser(*O*-Boc)-OMe (1 mmol, 0.398 g) for Boc-L-Ser(*O*-Boc)-OMe to give **3c** (0.238 g, 85%). M.p. 93.5–94.5 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.23 (d, J = 8.4 Hz, 2 H, ArH), 7.54 (d, J = 8.4 Hz, 2 H, ArH), 7.33 (s, 1 H, NH), 6.24 (s, 1 H, βCH_2), 5.82 (d, J = 1.5 Hz, 1 H, βCH_2), 5.26 [s, 2 H, CH_2 Z(NO_2)], 3.86 (s, 3 H, CH_3 CO_2Me) ppm. ^{13}C NMR ($CDCl_3$): δ = 164.08 (C=O), 152.59 (C=O), 147.71 (C), 143.18 (C), 130.72 (αC), 128.25 (CH), 123.80 (CH), 106.54 (βCH_2), 65.41 (CH_2), 53.04 (OCH_3) ppm. $C_{12}H_{12}N_2O_6$ (280.24): calcd. C 51.43, H 4.32, N 10.00; found C 51.48, H 4.21, N 9.88.

Boc-*Z*-ΔAbu-OMe (3e): The same procedure described for the preparation of **3a** was followed substituting Boc-L-Thr(*O*-Boc)-OMe (1 mmol, 0.333 g) for Boc-L-Ser(*O*-Boc)-OMe to give **3e** (0.211 g, 98%).[1]

Z-*Z*-ΔAbu-OMe (3f): The same procedure described for the preparation of **3a** was followed substituting Z-L-Thr(*O*-Boc)-OMe (1 mmol, 0.367 g) for Boc-L-Ser(*O*-Boc)-OMe to give **3f** (0.209 g, 84%).[1,7d]

Synthesis of Z(NO_2)-*Z*-ΔAbu-OMe (3g): The same procedure described for the preparation of **3a** was followed substituting Z(NO_2)-L-Thr(*O*-Boc)-OMe (1 mmol, 0.412 g) for Boc-L-Ser(*O*-Boc)-OMe to give **3g** (0.280 g, 95%).[1]

Tos-*Z*-ΔAbu-OMe (3h): The same procedure described for the preparation of **3a** was followed substituting Tos-L-Thr(*O*-Boc)-OMe (1 mmol, 0.387 g) for Boc-L-Ser(*O*-Boc)-OMe to give **3h** (0.245 g, 91%). M.p. 118.5–119.5 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.67 (d, J = 8.7 Hz, 2 H, ArH), 7.27 (d, J = 8.7 Hz, 2 H, ArH), 6.99 (q, J = 7.2 Hz, 1 H, βCH), 6.06 (s, 1 H, NH), 3.43 (s, 3 H, CH_3 CO_2Me), 2.41 (s, 3 H, CH_3 Tos), 2.04 (d, J = 7.2 Hz, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 164.32 (C=O), 143.82 (C), 140.32 (βCH), 136.15 (C), 129.35 (CH), 127.48 (CH), 125.65 (αC), 52.20 (OCH_3), 21.50 (CH_3 Tos), 15.00 (γCH_3) ppm. $C_{12}H_{15}NO_4S$ (269.32): calcd. C 53.52, H 5.61, N 5.20, S 11.91; found C 53.30, H 5.63, N 5.33, S 11.82.

Boc-*Z*-ΔPhe-OMe (3i): The same procedure described for the preparation of **3a** was followed substituting Boc-L-Phe(*O*-Boc)-OMe (1 mmol, 0.395 g) for Boc-L-Ser(*O*-Boc)-OMe to give **3i** (0.244 g, 88%).[3b]

One-Pot Synthesis of *N*-Acyldehydroamino Acid Esters 3a–j from *N*-Acyl-β-hydroxyamino Acid Esters

Boc-ΔAla-OMe (3a): DMAP (0.1 equiv.) was added to a solution of Boc-L-Ser-OMe (1 mmol, 0.219 g) in dry acetonitrile (1 mol dm^{-3}) followed by di-*tert*-butyl dicarbonate (1.0 equiv.) under rapid stirring at room temperature. The reaction was monitored by TLC (diethyl ether/*n*-hexane, 1:1) until all the reactant had been consumed. Then TMG (2% in volume) was added and stirring was continued and the reaction followed by TLC. When all the reactant had been consumed evaporation at reduced pressure gave a residue that was partitioned between diethyl ether (100 mL) and $KHSO_4$ (30 mL, 1 mol dm^{-3}). The organic phase was thoroughly washed with $KHSO_4$ (1 mol dm^{-3}), $NaHCO_3$ (1 mol dm^{-3}) and saturated brine (2 × 30 mL, each), and dried with $MgSO_4$. Removal of the solvent afforded pure **3a** (0.165 g, 82%).[1]

Z-ΔAla-OMe (3b): The same procedure described for the preparation of **3a** was followed substituting Z-L-Ser-OMe (1 mmol, 0.254 g) for Boc-L-Ser-OMe to give **3b** (0.212 g, 90%).[10]

Z(NO_2)-ΔAla-OMe (3c): The same procedure described for the preparation of **3a** was followed substituting Z(NO_2)-L-Ser-OMe (1 mmol, 0.298 g) for Boc-L-Ser-OMe to give **3c** (0.252 g, 90%).

Tos-ΔAla-OMe (3d): The same procedure described for the preparation of **3a** was followed substituting Tos-L-Ser-OMe (1 mmol, 0.273 g) for Boc-L-Ser-OMe and stopping the reaction 5 min after the addition of TMG to give **3d** (0.166 g, 65%) as a white solid. M.p. 101.5–102.5 °C (diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.76 (d, J = 8.7 Hz, 2 H, ArH), 7.30 (d, J = 8.7 Hz, 2 H, ArH), 7.14 (s, 1 H, NH), 5.67 (d, J = 1.2 Hz, 1 H, βCH_2), 5.65 (t, J = 1.5 Hz, 1 H, βCH_2), 3.76 (s, 3 H, CH_3 CO_2Me), 2.42 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 163.64 (C=O), 144.32 (C), 135.35 (C), 130.77 (αC), 129.68 (CH), 127.56 (CH), 106.87 (βCH_2), 53.18 (OCH_3), 21.56 (CH_3 Tos) ppm. $C_{11}H_{13}NO_4S$ (255.29): calcd. C 51.75, H 5.13, N 5.49, S 12.56; found C 51.74, H 5.13, N 5.67, S 12.60. The other product isolated was Tos-NH_2. M.p. 125.5–126.5 °C (ref.[14] 137.0–138.0 °C) (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.83 (d, J = 8.4 Hz, 2 H, ArH), 7.33 (d, J = 8.4 Hz, 2 H, ArH), 4.77 (br. s, 2 H, NH_2), 2.45 (s, 9 H, CH_3 Tos) ppm.

Boc-*Z*-ΔAbu-OMe (3e): The same procedure described for the preparation of **3a** was followed substituting Boc-L-Thr-OMe (1 mmol, 0.233 g) for Boc-L-Ser-OMe to give **3e** (0.177 g, 82%).[1]

Z-*Z*-ΔAbu-OMe (3f): The same procedure described for the preparation of **3a** was followed substituting Z-L-Thr-OMe (1 mmol, 0.267 g) for Boc-L-Ser-OMe to give **3f** (0.207 g, 83%).[1]

Z(NO_2)-*Z*-ΔAbu-OMe (3g): The same procedure described for the preparation of **3a** was followed substituting Z(NO_2)-L-Thr-OMe (1 mmol, 0.312 g) for Boc-L-Ser-OMe to give **3g** (0.268 g, 91%).[1]

Tos-*Z*-ΔAbu-OMe (3h): The same procedure described for the preparation of **3a** was followed substituting Tos-L-Thr-OMe (1 mmol, 0.287 g) for Boc-L-Ser-OMe to give **3h** (0.232 g, 86%).

Boc-*Z*-ΔPhe-OMe (3i): The same procedure described for the preparation of **3a** was followed substituting Boc-D,L-Phe-OMe (1 mmol, 0.295 g) for Boc-L-Ser-OMe to give **3i** (0.240 g, 81%).[3b]

Tos-*Z*-ΔPhe-OMe (3j): The same procedure described for the preparation of **3a** was followed substituting Tos-D,L-Phe(β-OH)-OMe (1 mmol, 0.349 g) for Boc-L-Ser-OMe to give **3j** (0.268 g, 81%). M.p. 147.5–148.5 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.88–7.85 (m, 2 H, ArH), 7.67 (d, J = 8.4 Hz, 2 H, ArH), 7.53 (s, 1 H, βCH), 7.38–7.36 (m, 3 H, ArH), 7.29–7.23 (m, 2 H, ArH), 6.20 (br. s, 1 H, NH), 3.54 (s, 3 H, CH_3 CO_2Me), 2.41 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 165.35 (C=O), 143.88 (C), 137.73 (CH), 136.25 (C), 132.64 (C), 131.05 (CH), 130.36 (CH), 129.32 (CH), 128.39 (CH), 127.50 (CH), 122.61 (C), 52.54 (OCH_3), 21.51 (CH_3 Tos) ppm. $C_{17}H_{17}NO_4S$ (331.39): calcd. C 61.61, H 5.17, N 4.23, S 9.68; found C 61.59, H 5.17, N 4.29, S 9.61.

Synthesis of the Methyl Esters of *N*-Protected β-Brominated Dehydroamino Acids 4a–c, 5e–h and 6i,j

Boc-ΔAla(β,β-Br)-OMe (4a): The synthesis of this compound has been described elsewhere.[6a]

Z-ΔAla(β,β-Br)-OMe (4b): Z-ΔAla-OMe (5 mmol, 1.18 g) was dissolved in dichloromethane (0.1 mol dm^{-3}) and *N*-bromosuccinimide (2.5 equiv.) was added with vigorous stirring. After reacting for 16 h, triethylamine (1.5 equiv.) was added and stirring was continued for an additional hour. The solvent was then evaporated at reduced pressure and the residue partitioned between dichloromethane (100 mL) and $KHSO_4$ (50 mL, 1 mol dm^{-3}). The organic phase was washed with $KHSO_4$ (1 mol dm^{-3}), $NaHCO_3$ (1 mol dm^{-3}) and brine (3 × 30 mL, each). After drying with $MgSO_4$ the extract was taken to dryness at reduced pressure to afford **4b** (1.69 g, 86%). M.p. 103.5–104.5 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.38–7.35 (m, 5 H, ArH), 6.54 (br. s, 1 H, NH), 5.16 (s, 2 H, CH_2), 3.82 (s, 3 H, CH_3 CO_2Me) ppm. ^{13}C NMR ($CDCl_3$): δ = 162.17 (C=O), 151.93 (C=O), 135.10 (C), 132.40 (C), 128.67 (CH), 128.48 (CH), 119.72 (C), 68.39 (CH_2), 52.96 (OCH_3) ppm. $C_{12}H_{11}NO_4$ (393.03): C 36.67, H 2.82, N 3.56; found C 36.66, H 2.90, N 3.93.

Z(NO_2)-ΔAla(β,β-Br)-OMe (4c): The same procedure described for the preparation of **4b** was followed substituting **3c** (5 mmol, 1.40 g) for **3b** to give **4c** (1.64 g, 75%). M.p. 153.5–154.5 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.25 (d, J = 9.0 Hz, 2 H, ArH), 7.53 (d, J = 9.0 Hz, 2 H, ArH), 6.62 (br. s, 1 H, NH), 5.26 (s, 2 H, CH_2), 3.87 (s, 3 H, CH_3 CO_2Me) ppm. ^{13}C NMR ($CDCl_3$): δ = 162.10 (C=O), 151.59 (C=O), 147.87 (C), 142.19 (C), 131.73 (C), 128.50 (CH), 123.84 (CH), 82.06 (C), 66.58 (CH_2), 53.18 (OCH_3) ppm. $C_{12}H_{10}N_2O_6Br_2$ (438.03): C 32.90, H 2.30, N 6.40; found C 33.35, H 2.41, N 6.63.

Boc-ΔAbu(β-Br)-OMe (5e): The synthesis of this compound has been described elsewhere.[13]

Z-ΔAbu(β-Br)-OMe (5f): The same procedure described for the preparation of **4b** was followed substituting **3f** (5 mmol, 1.25 g) for **3b** and by using 1.2 equiv. of NBS to give (*E*)-**5f** and (*Z*)-**5f** as a 1:1 *E*/*Z* mixture (1.46 g, 89%). The diastereomers were separated by column chromatography using a solvent gradient of neat petro-

leum ether to 40% diethyl ether/petroleum ether. (*E*)-**5f**: M.p. 141.5–142.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.36–7.33 (m, 5 H, ArH), 6.30 (br. s, 1 H, NH), 5.15 (s, 2 H, CH_2 Z), 3.81 (br. s, 3 H, CH_3 CO_2Me), 2.41 (s, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 164.06 (C=O), 153.53 (C=O), 135.53 (C), 128.57 (CH), 128.43 (CH), 128.28 (CH), 125.66 (C), 124.14 (C), 67.76 (CH_2), 52.37 (OCH_3), 25.92 (γCH_3) ppm. $C_{13}H_{14}NO_4Br$ (328.16): C 47.58, H 4.30, N 4.27; found C 47.74, H, 4.44, N 4.45. (*Z*)-**5f**: M.p. 97.5–98.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.41–7.32 (m, 5 H, ArH), 6.46 (br. s, 1 H, NH), 5.16 (s, 2 H, CH_2 Z), 3.81 (br. s, 3 H, CH_3 CO_2Me), 2.56 (s, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 162.91 (C=O), 153.25 (C=O), 135.47 (C), 128.57 (CH), 128.44 (CH), 128.32 (CH), 126.90 (C), 122.47 (C), 67.77 (CH_2), 52.59 (OCH_3), 24.69 (γCH_3) ppm. $C_{13}H_{14}NO_4Br$ (328.16): C 47.58, H 4.30, N 4.27; found C 47.56, H 4.38, N 4.47.

Z(NO_2)-ΔAbu(β-Br)-OMe (5g): The same procedure described for the preparation of **5f** was followed substituting **3g** (5 mmol, 1.47 g) for **3f** to give (*E*)-**5g** and (*Z*)-**5g** as a 1:1 mixture (1.49 g, 80%). The diastereomers were separated by column chromatography using a solvent gradient of neat petroleum ether to 30% diethyl ether/petroleum ether. (*E*)-**5g**: M.p. 140.5–141.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.22 (d, *J* = 8.4 Hz, 2 H, ArH), 7.52 (d, *J* = 8.4 Hz, 2 H, ArH), 6.34 (br. s, 1 H, NH), 5.24 [s, 2 H, CH_2 Z(NO_2)], 3.81 (br. s, 3 H, CH_3 CO_2Me), 2.44 (s, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 163.95 (C=O), 152.90 (C=O), 147.74 (C), 142.89 (C), 128.26 (CH), 125.40 (C), 125.25 (C), 123.79 (CH), 66.08 (CH_2), 52.48 (OCH_3), 26.18 (γCH_3) ppm. $C_{13}H_{13}N_2O_6Br$ (373.16): C 41.84, H 3.51, N 7.51, found C 41.85, H 3.59, N 7.74. (*Z*)-**5g**: M.p. 143.5–144.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.22 (d, *J* = 8.4 Hz, 2 H, ArH), 7.52 (d, *J* = 8.4 Hz, 2 H, ArH), 6.52 (br. s, 1 H, NH), 5.24 [s, 2 H, CH_2 Z(NO_2)], 3.79 (br. s, 3 H, CH_3 CO_2Me), 2.59 (s, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 162.70 (C=O), 152.87 (C=O), 147.71 (C), 142.88 (C), 128.24 (CH), 126.49 (C), 124.68 (C), 123.75 (CH), 66.04 (CH_2), 52.65 (OCH_3), 24.88 (γCH_3) ppm. $C_{13}H_{13}N_2O_6Br$ (373.16): C 41.84, H 3.51, N 7.51; found C 41.78, H 3.57, N 7.68.

Tos-ΔAbu(β-Br)-OMe (5h): The same procedure described for the preparation of **5f** was followed substituting **3h** (5 mmol, 1.35 g) for **3f** to give (*E*)-**5h** and (*Z*)-**5h** as a 1:9 *E*/*Z* mixture (1.64 g, 94%). The diastereomers were separated by column chromatography using a solvent gradient of neat petroleum ether to 40% diethyl ether/petroleum ether. (*E*)-**5h**: Oil. ^{1}H NMR ($CDCl_3$): δ = 7.68 (d, *J* = 8.4 Hz, 2 H, ArH), 7.31 (d, *J* = 8.4 Hz, 2 H, ArH), 6.13 (s, 1 H, NH), 3.37 (s, 3 H, CH_3 CO_2Me), 2.63 (s, 3 H, γCH_3), 2.43 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 166.39 (C=O), 137.36 (C), 135.75 (C), 129.70 (C), 129.47 (CH), 127.32 (CH), 123.55 (C), 52.09 (OCH_3), 28.21 (γCH_3), 21.55 (CH_3 Tos) ppm. (*Z*)-**5h**: M.p. 112.0–113.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.73 (d, *J* = 8.4 Hz, 2 H, ArH), 7.31 (d, *J* = 8.4 Hz, 2 H, ArH), 6.29 (s, 1 H, NH), 3.77 (s, 3 H, CH_3 CO_2Me), 2.55 (s, 3 H, γCH_3), 2.44 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 163.06 (C=O), 144.21 (C), 136.14 (C), 130.86 (C), 129.61 (CH), 127.31 (CH), 126.53 (C), 52.76 (OCH_3), 25.45 (γCH_3), 21.60 (CH_3 Tos) ppm. $C_{12}H_{14}NO_4SBr$ (348.22): C 41.39, H 4.05, N 4.02, S 9.21; found C 41.56, H 4.05, N 4.11, S 9.19.

Boc-ΔPhe(β-Br)-OMe (6i): The same procedure described for the preparation of **5f** was followed substituting **3i** for **3f** to give (*E*)-**6i** and (*Z*)-**6i** as a 1:2 mixture (97%).[6b]

Tos-Z-ΔPhe(β-Br)-OMe (6j): The same procedure described for the preparation of **5f** was followed substituting **3j** (2 mmol, 0.66 g) for **3f** to give (*Z*)-**6j** (0.64 g, 78%). M.p. 133.0–134.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.83 (d, *J* = 8.4 Hz, 2 H, ArH), 7.38–7.22 (m, 7 H, ArH), 6.63 (s, 1 H, NH), 3.58 (s, 3 H, CH_3 CO_2Me), 2.48 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 163.26 (C=O), 144.49 (C), 137.00 (C), 135.95 (C), 129.68 (CH), 129.65 (CH), 128.46 (CH), 128.37 (C), 128.30 (CH), 127.36 (CH), 123.65 (βC), 52.82 (OCH_3), 21.66 (CH_3 Tos) ppm. $C_{17}H_{16}NO_4SBr$ (410.28): C 49.77, H 3.93, N 3.41, S 7.82; found C 49.63, H 4.16, N 3.51, S 7.65.

Synthesis of the Methyl Esters of *N*-Acyldipeptides 7a–j,l: In all cases the *N*-protected amino acid was treated with the corresponding amino acid methyl ester in acetonitrile using the standard DCC/HOBt procedure.

Tos-Gly-L-Ser-OMe (7a): The procedure referred to above was followed using Tos-Gly-OH (10 mmol) and HCl·H-L-Ser-OMe (10 mmol) giving **7a** as a white solid (2.35 g, 71%). M.p. 102.0–103.0 °C (from ethyl acetate). ^{1}H NMR ($CDCl_3$): δ = 7.75 (d, *J* = 7.8 Hz, 2 H, ArH), 7.42 (d, *J* = 7.8 Hz, 1 H, NH), 7.33 (d, *J* = 7.8 Hz, 2 H, ArH), 6.05 (br. s, 1 H, NH), 4.65–4.63 (m, 1 H, αCH), 4.02–3.83 (m, 2 H, CH_2), 3.78 (s, 3 H, CH_3 CO_2Me), 3.66–3.64 (m, 2 H, CH_2), 3.35 (br. s, 1 H, OH), 2.43 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR (DMSO): δ = 170.80 (C=O), 167.74 (C=O), 142.79 (C), 137.33 (C), 129.58 (CH), 126.70 (CH), 61.16 (αCH), 54.49 (CH_2), 51.99 (OCH_3), 45.02 (CH_2), 21.01 (CH_3 Tos) ppm. $C_{13}H_{18}N_2O_6S$ (330.30): calcd. C 47.27, H 5.49, N 8.48, S 9.69; found C 47.40, H 5.49, N 8.24, S 9.48.

Tos-L-Ala-L-Ser-OMe (7b): The procedure referred to above was followed using Tos-L-Ala-OH (10 mmol) and HCl·H-L-Ser-OMe (10 mmol) giving **7b** (2.48 g, 72%). M.p. 152.5–154.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.77 (d, *J* = 8.1 Hz, 2 H, ArH), 7.46 (d, *J* = 7.5 Hz, 1 H, NH), 7.30 (d, *J* = 8.1 Hz, 2 H, ArH), 6.14 (d, *J* = 7.8 Hz, 1 H, NH), 4.58–4.53 (m, 1 H, αCH Ser), 3.97–3.79 (m, 3 H, αCH Ala + βCH_2 Ser), 3.75 (s, 3 H, CH_3 CO_2Me), 2.41 (s, 3 H, CH_3 Tos), 1.23 (d, *J* = 6.9 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 172.16 (C=O), 170.68 (C=O), 143.91 (C), 136.62 (C), 129.78 (CH), 127.24 (CH), 62.47 (CH_2), 54.81 (CH), 52.76 (OCH_3), 52.40 (CH), 21.51 (CH_3 Tos), 18.73 (βCH_3) ppm. $C_{14}H_{20}N_2O_6S$ (344.39): calcd. C 40.83, H 5.85, N 8.13, S 9.31; found C 49.12, H 5.85, N 8.13, S 9.31.

Tos-Gly-L-Thr-OMe (7c): The procedure referred to above was followed using Tos-Gly-OH (10 mmol) and HCl·H-L-Thr-OMe (10 mmol) giving **7c** as a white solid (2.27 g, 66%). M.p. 75.0–76.5 °C (from ethyl acetate/diethyl ether). ^{1}H NMR ($CDCl_3$): δ = 7.76 (d, *J* = 8.1 Hz, 2 H, ArH), 7.32 (d, *J* = 8.1 Hz, 2 H, ArH), 7.25 (br. s, 1 H, NH Thr), 5.99 (br. t, 1 H, NH Gly), 4.57–4.53 (m, 1 H, βCH Thr), 4.38–4.35 (m, 1 H, αCH Thr), 3.77 (s, 3 H, CH_3 CO_2Me), 3.69 (d, *J* = 6.6 Hz, 2 H, CH_2 Gly), 2.43 (s, 3 H, CH_3 Tos), 1.21 (d, *J* = 6.6 Hz, 3 H, γCH_3 Thr) ppm. ^{13}C NMR ($CDCl_3$): δ = 171.49 (C=O), 169.02 (C=O), 144.04 (C), 135.58 (C), 129.88 (CH), 127.19 (CH), 67.87 (CH), 57.58 (CH), 52.76 (OCH_3), 45.66 (CH_2), 21.52 (CH_3 Tos), 19.89 (γCH_3) ppm. $C_{14}H_{20}N_2O_6S$ (344.33): calcd. C 48.83, H 5.85, N 8.14, S 9.29; found C 48.68, H 5.98, N 8.06, S 9.35.

Tos-L-Ala-L-Thr-OMe (7d): The procedure referred to above was followed using Tos-L-Ala-OH (10 mmol) and HCl·H-L-Thr-OMe (10 mmol) giving **7d** as a white solid (3.44 g, 96%). M.p. 140.0–141.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.77 (d, *J* = 8.1 Hz, 2 H, ArH), 7.29 (d, *J* = 8.1 Hz, 2 H, ArH), 7.20 (d, *J* = 9.0 Hz, 1 H, NH Ala), 6.02 (d, *J* = 8.1 Hz, 1 H, NH Thr), 4.50–4.46 (m, 1 H, βCH Thr), 4.33–4.30 (m, 1 H, αCH Thr), 3.97–3.89 (m, 1 H, αCH Ala), 3.74 (s, 3 H, CH_3 CO_2Me), 2.41 (s, 3 H, CH_3 Tos), 1.28 (d, *J* = 6.9 Hz, 3 H, γCH_3 Ala), 1.08 (d, *J* = 6.3 Hz, 3 H, γCH_3 Thr) ppm. ^{13}C NMR ($CDCl_3$): δ = 172.45 (C=O),

171.18 (C=O), 143.72 (C), 136.71 (C), 129.75 (CH), 127.16 (CH), 67.92 (αCH Thr), 57.47 (βCH Thr), 52.62 (OCH_3), 52.32 (αCH Ala), 21.47 (CH_3 Tos), 19.67 (γCH_3), 19.34 (βCH_3) ppm. MS (FAB): *m*/*z* (%) = 359.08 (100) $[M + 1]^+$, 299.07 (25.17), 198.11 (56.09). HRMS (FAB): calcd. for $C_{15}H_{23}N_2O_6S$ [M + 1] 359.1277; found 359.1278. $C_{15}H_{23}N_2O_6S$ (358,41): calcd. C 50.27, H 6.19, N 7.82, S 8.95; found C 50.18, H 6.12, N 7.80, S 8.73.

Tos-Gly-D,L-Phe(β-OH)-OMe (7e): The procedure referred to above was followed using Tos-Gly-OH (10 mmol) and HCl·H-D,L-Phe(β-OH)-OMe (10 mmol) giving **7e** as a white solid (3.05 g, 75%). M.p. 118.0–120.0 °C (from ethyl acetate/diethyl ether). ^{1}H NMR ($CDCl_3$): δ = 7.71 (d, *J* = 8.4 Hz, 2 H, ArH Tos), 7.36–7.28 [m, 7 H, ArH Tos + ArH Phe(β-OH)], 5.51 (br. s, 1 H, NH Gly), 5.29 (d, *J* = 3.3 Hz, 1 H, βCH), 4.78 [dd, *J* = 3.3, *J* = 8.7 Hz, 1 H, αCH Phe(β-OH)], 3.73 (s, 3 H, CH_3 CO_2Me), 3.55–3.53 (m, 2 H, CH_2 Gly), 2.42 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.92 (C=O), 168.67 (C=O), 143.85 (C), 139.41 (C), 135.68 (C), 129.79 (CH), 128.38 (CH), 128.12 (CH), 127.09 (CH), 125.91 (CH), 73.36 (CH), 58.44 (CH), 52.72 (OCH_3), 45.46 (CH_2), 21.48 (CH_3 Tos) ppm. $C_{19}H_{22}N_2O_6S$ (406.40): calcd. C 56.15, H 5.46, N 6.89, S 7.87; found C 55.80, H 5.60, N 6.84, S 7.49.

Tos-L-Ala-D,L-Phe(β-OH)-OMe (7f): The procedure referred to above was followed using Tos-L-Ala-OH (10 mmol) and HCl·H-D,L-Phe(β-OH)-OMe (10 mmol) giving **7f** as a diastereomeric mixture (4.01 g, 95%). Crystallization from ethyl acetate/*n*-hexane allowed the isolation of one of the diastereomers as a white solid. M.p. 173.0–174.0 °C. ^{1}H NMR (DMSO): δ = 8.15 [d, *J* = 9.0 Hz, 1 H, NH Phe(β-OH)], 7.77 (d, *J* = 8.1 Hz, 1 H, NH Ala), 7.61 (d, *J* = 8.1 Hz, 2 H, ArH Tos), 7.34–7.18 [m, 7 H, ArH Tos + ArH Phe(β-OH)], 5.89 [d, *J* = 4.5 Hz, 1 H, OH Phe(β-OH)], 5.11–5.09 [m, 1 H, βCH Phe(β-OH)], 4.46 [dd, *J* = 2.7, *J* = 9.0 Hz, 1 H, αCH Phe(β-OH)], 3.94–3.84 (m, 1 H, αCH Ala), 3.65 (s, 3 H, CH_3 CO_2Me), 2.35 (s, 3 H, CH_3 Tos), 0.68 (d, *J* = 7.2 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR (DMSO): δ = 171.36 (C=O), 170.38 (C=O), 142.34 (C), 141.41 (C), 138.45 (C), 129.35 (CH), 127.66 (CH), 127.14 (CH), 126.48 (CH), 126.20 (CH), 72.18 [βCH Phe(β-OH)], 57.90 [αCH Phe(β-OH)], 52.00 (OCH_3), 51.28 (αCH Ala), 20.96 (CH_3 Tos), 18.85 (βCH_3 Ala) ppm. $C_{20}H_{24}N_2O_6S$ (420.48): calcd. C 57.13, H 5.75, N 6.66, S 7.63; found C 57.13, H 5.69, N 6.63, S 7.62. The other diastereomer was obtained from the mother liquor as an oil. ^{1}H NMR ($CDCl_3$): δ = 7.69 (d, *J* = 8.4 Hz, 2 H, ArH Tos), 7.33–7.22 [m, 8 H, ArH Tos + ArH Phe(β-OH) + NH], 5.51 (br. d, *J* = 7.5 Hz, 1 H, NH), 5.25 [d, *J* = 3.3 Hz, 1 H, βCH Phe(β-OH)], 4.74 [dd, *J* = 3.3, *J* = 8.6 Hz, 1 H, αCH Phe(β-OH)], 3.83–3.76 (m, 1 H, αCH Ala), 3.70 (s, 3 H, CH_3 CO_2Me), 3.42 (br. s, 1 H, OH), 2.41 (s, 3 H, CH_3 Tos), 1.11 (d, *J* = 6.9 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 171.85 (C=O), 170.57 (C=O), 143.63 (C), 139.57 (C), 136.55 (C), 129.71 (CH), 128.27 (CH), 127.94 (CH), 127.03 (CH), 125.92 (CH), 73.41 [βCH Phe(β-OH)], 58.35 [αCH Phe(β-OH)], 52.58 (OCH_3), 52.34 (αCH Ala), 21.47 (CH_3 Tos), 18.82 (βCH_3 Ala) ppm.

Boc-L-Ala-L-Ser-OMe (7g): The procedure referred to above was followed using Boc-L-Ala-OH (10 mmol) and HCl·H-L-Ser-OMe (10 mmol of) giving **7g** as an oil (2.35 g, 81%).[15]

Boc-Gly-L-Thr-OMe (7h): The procedure referred to above was followed using Boc-Gly-OH (10 mmol) and HCl·H-L-Thr-OMe (10 mmol) giving **7h** as an oil (2.12 g, 73%). ^{1}H NMR ($CDCl_3$): δ = 7.00 (d, *J* = 9.0 Hz, 1 H, NH Thr), 5.37 (br. s, 1 H, NH Gly), 4.61 (dd, *J* = 2.7, *J* = 9.0 Hz, 1 H, αCH Thr), 4.36–4.32 (m, 1 H, βCH Thr), 3.88 (d, *J* = 6.0 Hz, 2 H, CH_2 Gly), 3.77 (s, 3 H, CH_3 CO_2Me), 1.45 (s, 9 H, CH_3 Boc), 1.22 (d, *J* = 6.3 Hz, 3 H, γCH_3 ΔAbu) ppm. ^{13}C NMR ($CDCl_3$): δ = 171.45 (C=O), 170.40 (C=O), 156.18 (C=O), 80.12 [$C(CH_3)_3$], 67.74 (CH), 57.46 (CH), 52.51 (OCH_3), 43.88 (CH_2), 28.17 [$C(CH_3)_3$], 19.80 (γCH_3) ppm.

Boc-Gly-L-Ser-OMe (7i): The procedure referred to above was followed using Boc-Gly-OH (10 mmol) and HCl·H-L-Ser-OMe (10 mmol) giving **7i** as an oil (2.04 g, 74%). ^{1}H NMR ($CDCl_3$): δ = 7.32 (d, *J* = 7.5 Hz, 1 H, NH Thr), 5.60 (s, 1 H, NH Gly), 4.66–4.62 (m, 1 H, αCH Ser), 3.93 (br. t, *J* = 5.1 Hz, 2 H, βCH_2 Ser), 3.84 (br. s, 2 H, CH_2 Gly), 3.76 (s, 3 H, CH_3 CO_2Me), 3.34 (br. s, 1 H, OH), 1.43 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.89 (C=O), 170.00 (C=O), 156.36 (C=O), 80.42 [$C(CH_3)_3$], 62.48 (CH_2), 54.69 (CH), 52.67 (OCH_3), 40.01 (CH_2), 28.21 [$C(CH_3)_3$] ppm.

Boc-Gly-D,L-Phe(β-OH)-OMe (7j): The procedure referred to above was followed using Boc-Gly-OH (10 mmol) and HCl·H-D,L-Phe(β-OH)-OMe (10 mmol) giving **7j** as a white solid (3.03 g, 86%). M.p. 132.5–133.5 °C (from diethyl ether/diethyl ether). ^{1}H NMR ($CDCl_3$): δ = 7.35–7.24 (m, 5 H, ArH), 7.16 (br. d, *J* = 8.1 Hz, 1 H, NH), 5.30 (br. s, 1 H, NH), 5.25 (d, *J* = 3.3 Hz, 1 H, β-CH), 4.83 (dd, *J* = 3.3, *J* = 8.7 Hz, 1 H, α-CH), 3.73–3.69 (m, 5 H, CH_3 CO_2Me + CH_2 Gly), 1.42 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.85 (C=O), 169.87 (C=O), 155.96 (C=O), 139.64 (C), 128.31 (CH), 128.00 (CH), 125.79 (CH), 80.14 [*C*inline style="font-weight: bold; vertical-align: sub;"$(CH_3)_3$], 73.35 (CH), 58.18 (CH), 52.60 (OCH_3), 43.75 (CH_2), 28.19 [$C(CH_3)_3$] ppm. $C_{17}H_{24}N_2O_6$ (352.38): calcd. C 57.94, H 6.86, N 7.95; found C 58.43, H 7.16, N 8.41.

Z-Gly-L-Ser-OMe (7l): The procedure referred to above was followed using Z-Gly-OH (10 mmol) and HCl·H-L-Ser-OMe (10 mmol) giving **7l** as a white solid (2.82 g, 91%). M.p. 93.0–94.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.34–7.30 (m, 5 H, ArH), 7.21 (d, *J* = 7.5 Hz, 1 H, NH Ser), 5.79 (br. s, 1 H, NH Gly), 5.11 (s, 2 H, CH_2 Z), 4.67–4.62 (m, 1 H, αCH Ser), 3.98–3.92 (m, 4 H, βCH_2 Ser + CH_2 Gly), 3.75 (s, 3 H, CH_3 CO_2Me) ppm. ^{13}C NMR (DMSO): δ = 170.88 (C=O), 169.54 (C=O), 156.89 (C=O), 135.99 (C), 128.53 (CH), 128.24 (CH), 128.05 (CH), 67.29 (CH_2), 62.61 (αCH), 54.69 (CH_2), 52.76 (OCH_3), 44.29 (CH_2) ppm. $C_{14}H_{18}N_2O_6$ (310.30): calcd. C 54.19, H 5.85 N 9.03; found C 54.26, H 5.84, N 9.21.

Synthesis of the Methyl Esters of *N*-Protected *N*,*N*′-Bis(*tert*-butyloxycarbonyl)dehydrodipeptides 8a,c–h

Tos-Gly(*N*-Boc)-ΔAla(*N*-Boc)-OMe (8a): The synthesis of this compound has been described elsewhere.[3a]

Tos-Gly(*N*-Boc)-*Z*-ΔAbu(*N*-Boc)-OMe (8c): DMAP (0.3 equiv.) was added to a solution of **7c** (5 mmol, 1.72 g) in dry acetonitrile (1 mol dm^{-3}) followed by di-*tert*-butyl dicarbonate (3.3 equiv.) under rapid stirring at room temperature. The reaction was stirred for 12 h while monitored by TLC (diethyl ether/*n*-hexane, 2:1). Evaporation at reduced pressure gave a residue that was partitioned between diethyl ether (200 mL) and $KHSO_4$ (100 mL, 1 mol dm^{-3}). The organic phase was thoroughly washed with $KHSO_4$ (1 mol dm^{-3}), $NaHCO_3$ (1 mol dm^{-3}) and saturated brine (3 × 50 mL, each), and dried with $MgSO_4$. Removal of the solvent afforded **8c** as an oil (2.40 g, 91%). M.p. 61.0–62.0 °C (from diethyl ether/petroleum ether). ^{1}H NMR ($CDCl_3$): δ = 7.92 (d, *J* = 8.1 Hz, 2 H, ArH), 7.28 (d, *J* = 8.1 Hz, 2 H, ArH), 7.06 (q, *J* = 7.2 Hz, 1 H, CH ΔAbu), 5.34 (d, *J* = 18.9 Hz, 1 H, CH_2 Gly), 5.26 (d, *J* = 18.9 Hz, 1 H, CH_2 Gly), 3.77 (s, 3 H, CH_3 CO_2Me), 2.43 (s, 3 H, CH_3 Tos), 1.73 (d, *J* = 7.2 Hz, 3 H, γCH_3 ΔAbu), 1.48 (s, 9 H, CH_3 Boc), 1.31 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.61 (C=O), 163.70 (C=O), 151.41 (C=O), 150.55 (C=O), 144.13 (C), 138.69 (C), 136.82 (C), 129.21 (CH), 128.97 (CH), 128.71 (CH),

84.49 [$(CH_3)_3CO$], 84.22 [$(CH_3)_3CO$], 52.18 (OCH_3), 51.06 (CH_2), 27.79 [$C(CH_3)_3$], 27.73 [$C(CH_3)_3$], 21.62 (CH_3 Tos), 13.52 (CH_3) ppm. $C_{24}H_{34}N_2O_9S$ (526.55): calcd. C 54.75, H 6.51, N 5.32, S 6.08; found C 54.71, H 6.53, N 5.25, S 5.98.

Tos-L-Ala(*N*-Boc)-*Z*-ΔAbu(*N*-Boc)-OMe (8d): The same procedure described above was used substituting compound **7d** (5 mmol, 1.79g) for compound **7c** giving **8d** as an oil (1.41g, 52%). ^{1}H NMR ($CDCl_3$) doubling of signals due to the presence of two conformers:[16] δ = 7.86–7.81 (m, 4 H, ArH), 7.29–7.24 (m, 4 H, ArH), 7.06 (q, J = 7.2 Hz, 1 H, CH ΔAbu), 7.00 (q, J = 6.9 Hz, 1 H, CH ΔAbu), 6.42 (q, J = 7.2 Hz, 1 H, αCH Ala), 6.03 (q, J = 6.9 Hz, 1 H, αCH Ala), 3.77 (s, 3 H, CH_3 CO_2Me), 3.75 (s, 3 H, CH_3 CO_2Me), 2.42 (s, 3 H, CH_3 Tos), 2.41 (s, 3 H, CH_3 Tos), 1.93 (d, J = 7.2 Hz, 3 H, CH_3 ΔAbu), 1.74 (d, J = 7.2 Hz, 3 H, CH_3 ΔAbu), 1.50 (s, 9 H, CH_3 Boc), 1.48 (s, 9 H, CH_3 Boc), 1.33 (s, 9 H, CH_3 Boc), 1.31 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$) doubling of signals due to the presence of two conformers: δ = 172.14 (C=O), 171.59 (C=O), 163.96 (C=O), 151.23 (C=O), 151.09 (C=O), 150.69 (C=O), 150.58 (C=O), 144.07 (C), 143.82 (C), 138.81 (C), 138.06 (C), 137.19 (C), 136.97 (C), 129.50 (CH), 129.21 (CH), 129.11 (CH), 129.03 (CH), 128.29 (CH), 128.16 (CH), 84.38 [$(CH_3)_3CO$], 84.21 [$(CH_3)_3CO$], 84.18 [$(CH_3)_3CO$], 83.71 [$(CH_3)_3CO$], 57.93 (CH), 57.04 (CH), 52.18 (OCH_3), 27.77 [$C(CH_3)_3$], 27.70 [Cinline style="font-weight: bold; vertical-align: sub;"(CH_3)$_3$], 22.59 (CH_3 Tos), 21.58 (CH_3 Tos), 18.52 (CH_3 Ala), 17.09 (CH_3 Ala), 13.62 (CH_3 ΔAbu), 13.45 (CH_3 ΔAbu) ppm. $C_{25}H_{36}N_2O_9S$ (540.63): calcd. C 55.54, H 6.71, N 5.18, S 5.93; found C 55.86, H 6.69, N 5.12, S 5.63.

Tos-Gly(*N*-Boc)-*Z*-ΔPhe(*N*-Boc)-OMe (8e): The same procedure described above was used substituting compound **7e** (5 mmol, 2.03 g) for compound **7c** giving **8e** as an oil (2.83 g, 96%). M.p. 64.0–66.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.75 (d, J = 8.1 Hz, 2 H, ArH), 7.74 (s, 1 H, CH ΔPhe), 7.42–7.38 (m, 5 H, ArH), 7.17 (d, J = 8.1 Hz, 2 H, ArH), 5.30 (d, J = 6.6 Hz, 2 H, CH_2 Gly), 3.83 (s, 3 H, CH_3 CO_2Me), 2.38 (s, 3 H, CH_3 Tos), 1.31 (s, 9 H, CH_3 Boc), 1.30 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.22 (C=O) 164.42 (C=O), 151.07 (C=O), 150.41 (C=O), 144.06 (C), 137.98 (C), 132.61 (C), 130.23 (C), 129.33 (CH), 129.01 (CH), 128.91 (CH), 128.78 (CH), 125.99 (CH), 84.40 [$(CH_3)_3CO$], 84.32 [$(CH_3)_3CO$], 52.55 (OCH_3), 51.25 (CH_2), 27.68 [$C(CH_3)_3$], 27.51 [$C(CH_3)_3$], 21.62 (CH_3 Tos) ppm. $C_{29}H_{36}N_2O_9S$ (588.62): calcd. C 59.17, H 6.16, N 4.76, S 5.44; found C 59.27, H 6.33, N 4.62, S 5.18.

Tos-L-Ala(*N*-Boc)-*Z*-ΔPhe(*N*-Boc)-OMe (8f): The same procedure described above was used substituting compound **7f** (5 mmol, 2.10g) for compound **7c** giving **8f** as an oil (2.83 mg, 94%). M.p. 59.0–60.5 °C (from diethyl ether/petroleum ether). ^{1}H NMR ($CDCl_3$) doubling of signals due to the presence of two conformers:[16] δ = 7.84–7.70 (m, 6 H, ArH + CH ΔPhe), 7.44–7.37 (m, 10 H, ArH), 7.25–7.20 (m, 4 H, ArH), 6.46 (q, J = 6.9 Hz, 1 H, αCH Ala), 5.76 (br. d, J = 6.0 Hz, 1 H, αCH Ala), 3.85 (s, 3 H, CH_3 CO_2Me), 3.84 (s, 3 H, CH_3 CO_2Me), 2.40 (s, 3 H, CH_3 Tos), 2.38 (s, 3 H, CH_3 Tos), 1.81 (d, J = 6.9 Hz, 3 H, CH_3 Ala), 1.63–1.61 (m, 3 H, CH_3 Ala), 1.46 (s, 9 H, CH_3 Boc), 1.37 (s, 9 H, CH_3 Boc), 1.33 (s, 9 H, CH_3 Boc), 1.17 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$) doubling of signals due to the presence of two conformers: δ = 172.13 (C=O), 171.56 (C=O), 164.60 (C=O), 151.01 (C=O), 150.88 (C=O), 150.52 (C=O), 150.33 (C=O), 144.09 (C), 143.72 (C), 137.80 (C), 137.34 (C), 136.86 (C), 136.60 (C), 132.55 (C), 132.51 (C), 130.17 (CH), 129.98 (CH), 129.54 (CH), 129.38 (CH), 129.03 (CH), 129.00 (CH), 128.95 (CH), 128.65 (CH), 128.48 (CH), 128.31 (CH), 127.21 (C), 126.84 (C), 84.66 [$(CH_3)_3CO$], 84.48 [$(CH_3)_3CO$], 83.99 [$(CH_3)_3CO$], 83.85 [$(CH_3)_3CO$], 57.70 (CH), 56.53 (CH), 52.52 (OCH_3), 27.71 [$C(CH_3)_3$], 27.62 [$C(CH_3)_3$], 27.56 [$C(CH_3)_3$], 27.52 [$C(CH_3)_3$], 21.55 (CH_3 Tos), 18.20 (CH_3 Ala), 16.86 (CH_3 Ala) ppm. $C_{30}H_{38}N_2O_9S$ (602,70): calcd. C 59.79, H 6.35, N 4.65, S 5.32; found C 59.84, H 6.37, N 4.84, S 5.14.

Boc-L-Ala(*N*-Boc)-ΔAla(*N*-Boc)-OMe (8g): The synthesis of this compound has been described elsewhere.[1]

Boc-Gly(*N*-Boc)-*Z*-ΔAbu(*N*-Boc)-OMe (8h): The same procedure described above was used substituting compound **7h** (5 mmol, 1.45 g) for compound **7c** giving **8h** as an oil (1.94 g, 82%). M.p. 91.0–92.0 °C (*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.03 (q, J = 7.2 Hz, 1 H, βCH ΔAbu), 5.04 (d, J = 18.3 Hz, 1 H, CH_2 Gly), 4.89 (d, J = 18.3 Hz, 1 H, CH_2 Gly), 3.75 (s, 3 H, CH_3 CO_2Me), 1.71 (d, J = 7.2 Hz, 3 H, γCH_3 ΔAbu), 1.49 (s, 18 H, CH_3 Boc), 1.46 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.92 (C=O), 163.81 (C=O), 152.18 (C=O), 151.52 (C=O), 138.34 (C), 128.80 (CH), 83.82 [$(CH_3)_3CO$], 82.59 [$(CH_3)_3CO$], 52.10 (OCH_3), 51.41 (CH_2), 27.93 [$C(CH_3)_3$], 27.77 [$C(CH_3)_3$], 13.51 (CH_3) ppm. $C_{22}H_{36}N_2O_9$ (472.54): calcd. C 55.92, H 7.68, N 5.93; found C 55.65, H 7.53, N 5.98.

Synthesis of the Methyl Esters of *N*-Protected Dehydrodipeptides 9a,c–h by Deprotection of the Methyl Esters of *N*-Protected *N*,*N*′-Bis(*tert*-butyloxycarbonyl)dehydrodipeptides

Tos-Gly-ΔAla-OMe (9a): A 10% solution of TFA was added to a solution of **8a** (3 mmol, 1.54 g) in dichloromethane (0.1 mol dm^{-3}) with vigorous stirring. The reaction was monitored by TLC and when no starting material was detected additional dichloromethane (50 mL) was added. The organic phase was then washed with $NaHCO_3$ (1 mol dm^{-3}) and brine (3 × 30 mL). After drying with $MgSO_4$ the extract was taken to dryness at reduced pressure to afford compound **9a** as an oil (0.90 g, 96%). Crystallization from diethyl ether afforded white crystals. M.p. 122.5–124.0 °C. ^{1}H NMR (DMSO): δ = 9.23 (s, 1 H, NH), 8.11 (br. s, 1 H, NH), 7.68 (d, J = 8.1 Hz, 2 H, ArH), 7.38 (d, J = 8.1 Hz, 2 H, ArH), 6.22 (s, 1 H, β-CH_2), 5.71 (s, 1 H, β-CH_2), 3.76 (s, 3 H, CH_3 CO_2Me), 3.60 (d, J = 5.4 Hz, 2 H, CH_2), 2.37 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 166.64 (C=O), 164.04 (C=O), 144.14 (C), 135.61 (C), 130.40 (C), 129.91 (CH), 127.16 (CH), 109.90 (=CH_2), 53.09 (OCH_3), 46.34 (CH_2), 21.51 (CH_3 Tos) ppm. $C_{13}H_{16}N_2O_5S$ (312.28): calcd. C 50.00, H 5.16, N 8.97, S 10.25; found C 49.83, H 5.19, N 8.96, S 10.39.

Tos-Gly-*Z*-ΔAbu-OMe (9c): The procedure described above was used substituting compound **8c** (3 mmol, 1.58 g) for **8a** to give **9c** as an oil (0.94 g, 96%). M.p. 111.5–113.0 °C (from diethyl ether). ^{1}H NMR ($CDCl_3$): δ = 7.77 (d, J = 8.1 Hz, 2 H, ArH), 7.51 (s, 1 H, NH ΔAbu), 7.34 (d, J = 8.1 Hz, 2 H, ArH), 6.87 (q, J = 7.5 Hz, 1 H, βCH ΔAbu), 5.34 (t, J = 6.3 Hz, 1 H, NH Gly), 3.77 (s, 3 H, CH_3 CO_2Me), 3.72 (d, J = 6.3 Hz, 2 H, CH_2 Gly), 2.45 (s, 3 H, CH_3 Tos), 1.73 (d, J = 7.5 Hz, 3 H, γCH_3 ΔAbu) ppm. ^{13}C NMR ($CDCl_3$): δ = 166.89 (C=O), 164.73 (C=O), 144.04 (C), 135.83 (C), 135.60 (C), 129.87 (CH), 127.18 (CH), 125.52 (CH), 52.42 (OCH_3), 45.91 (CH_2), 21.50 (CH_3 Tos), 14.36 (CH_3) ppm. $C_{14}H_{18}N_2O_5S$ (326.31): calcd. C 51.53, H 5.56, N 8.58, S 9.81; found C 51.21, H 5.50, N 8.47, S 9.85.

Tos-L-Ala-*Z*-ΔAbu-OMe (9d): The procedure described above was used substituting compound **8d** (3 mmol, 2.70 g) for **8a** to give **9d** as an oil (0.48 mg, 47%). M.p. 118.5–119.5 °C (from diethyl ether). ^{1}H NMR ($CDCl_3$): δ = 7.77 (d, J = 8.1 Hz, 2 H, ArH), 7.59 (s, 1 H, NH ΔAbu), 7.32 (d, J = 8.1 Hz, 2 H, ArH), 6.83 (q, J = 7.2 Hz, 1 H, βCH ΔAbu), 5.37 (d, J = 7.5 Hz, 1 H, NH Ala), 3.93 (m, 1 H, αCH Ala), 3.76 (s, 3 H, CH_3 CO_2Me), 2.43 (s, 3 H, CH_3 Tos),

1.68 (d, J = 7.2 Hz, 3 H, γCH_3 ΔAbu), 1.32 (d, J = 7.2 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.05 (C=O), 164.63 (C=O), 143.97 (C), 136.34 (C), 135.31 (C), 129.88 (CH), 127.19 (CH), 125.57 (CH), 52.68 (CH), 52.37 (OCH_3), 21.51 (CH_3 Tos), 19.02 (CH_3), 14.34 (CH_3) ppm. $C_{15}H_{20}N_2O_5S$ (340.40): calcd. C 52.93, H 5.92, N 8.23, S 9.42; found C 52.49, H 6.14, N 8.17, S 9.06.

Tos-Gly-*Z*-ΔPhe-OMe (9e): The procedure described above was used substituting compound **8e** (3 mmol, 1.77 g) for **8a** to give **9e** as an oil (1.07 g, 92%). M.p. 132.0–134.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.20 (s, 1 H, NH ΔPhe), 7.73 (d, J = 8.1 Hz, 2 H, ArH Tos), 7.53–7.30 (m, 8 H, ArH + βCH), 6.06 (t, J = 6.6 Hz, 1 H, NH Gly), 3.77 (s, 3 H, CH_3 CO_2Me), 3.65 (d, J = 6.6 Hz, 2 H, CH_2), 2.41 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 167.52 (C=O), 165.44 (C=O), 144.01 (C), 135.71 (C), 134.12 (C), 133.01 (CH), 129.92 (CH), 129.88 (CH), 129.81 (CH), 128.69 (CH), 127.14 (CH), 123.29 (C), 52.74 (OCH_3), 46.04 (CH_2), 21.49 (CH_3 Tos) ppm. $C_{19}H_{20}N_2O_5S$ (388.44): calcd. C 58.75, H 5.19, N 7.21, S 8.26; found C 58.50, H 5.27, N 7.32, S 8.12. HRMS (FAB): calcd. for $C_{19}H_{21}N_2O_5S$ 389.1171 [M + 1]; found 389.1186.

Tos-L-Ala-*Z*-ΔPhe-OMe (9f): The procedure described above was used substituting compound **8f** (3 mmol, 1.81 g) for **8a** to give **9f** as an oil (1.05 g, 87%). M.p. 133.5–134.5 °C (from diethyl ether). ^{1}H NMR ($CDCl_3$): δ = 7.95 (br. s, 1 H, NH ΔPhe), 7.72 (d, J = 8.1 Hz, 2 H, ArH Tos), 7.50–7.30 (m, 8 H, ArH + βCH ΔPhe), 5.35 (d, J = 7.5 Hz, 1 H, NH Ala), 3.90 (m, 1 H, αCH Ala), 3.82 (s, 3 H, CH_3 CO_2Me), 2.43 (s, 3 H, CH_3 Tos), 1.26 (d, J = 7.2 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.19 (C=O), 165.36 (C=O), 143.99 (C), 136.35 (C), 133.49 (C), 133.20 (CH), 129.89 (CH), 129.84 (CH), 129.69 (CH), 128.62 (CH), 127.14 (CH), 123.49 (C), 52.77 (CH), 52.67 (OCH_3), 21.52 (CH_3 Tos), 18.33 (CH_3) ppm. $C_{20}H_{22}N_2O_5S$ (402.47): calcd. C 59.69, H 5.51, N 6.96, S 7.97; found C 59.63, H 5.45, N 6.89, S 7.81.

Boc-L-Ala-ΔAla-OMe (9g): The procedure described above was used substituting compound **8g** (3 mmol, 1.42 g) for **8a** to give **9g** as a white solid (0.751 g, 92%). M.p. 81.0–82.5 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.45 (s, 1 H, NH ΔAla), 6.61 (s, 1 H, βCH_2 ΔAla), 5.91 (d, J = 1.5 Hz, 1 H, βCH_2 ΔAla), 4.97 (br. s, 1 H, NH Ala), 4.27–4.25 (m, 1 H, αCH Ala), 3.85 (s, 3 H, CH_3 CO_2Me), 1.46 (s, 9 H, CH_3 Boc), 1.41 (d, J = 7.2 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 171.50 (C=O), 164.24 (C=O), 155.40 (C=O), 130.79 (C), 109.22 (βCH_2), 80.52 [$(CH_3)_3CO$], 52.93 (OCH_3), 50.94 (αCH), 28.23 [C(CH_3)$_3$], 17.95 (βCH_3) ppm. $C_{12}H_{20}N_2O_5$ (272.30): calcd. C 52.93, H 7.40, N 10.29; found C 52.77, H 7.07, N 10.17.

Boc-Gly-*Z*-ΔAbu-OMe (9h): The procedure described above was used substituting compound **8h** (3 mmol, 1.42 g) for **8a** to give **9h** as a white solid (0.71 g, 87%). M.p. 100.0–101.5 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.52 (s, 1 H, NH ΔAbu), 6.85 (q, J = 7.2 Hz, 1 H, βCH ΔAbu), 5.26 (br. s, 1 H, NH Gly), 3.93 (d, J = 5.4 Hz, 2 H, CH_2 Gly), 3.76 (s, 3 H, CH_3 CO_2Me), 1.78 (d, J = 7.2 Hz, 3 H, γCH_3 ΔAbu), 1.46 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 168.21 (C=O), 164.75 (C=O), 156.11 (C=O), 134.86 (C), 125.77 (CH), 80.13 [$(CH_3)_3CO$], 52.21 (OCH_3), 44.28 (CH_2), 28.14 [C(CH_3)$_3$], 14.32 (γCH_3) ppm. $C_{12}H_{20}N_2O_5$ (272.30): calcd. C 52.93, H 7.40, N 10.29; found C 53.11, H 7.15, N 9.95.

Synthesis of *N*-Acyl-*O*-(*tert*-butyloxycarbonyl)dipeptide Esters 10b, 10h and 10i

Tos-L-Ala-L-Ser(*O*-Boc)-OMe (10b): DMAP (0.1 equiv.) was added to a solution of Tos-L-Ala-L-Ser-OMe (**7b**) (5 mmol, 1.72 g) in dry acetonitrile (1 mol dm^{-3}) followed by di-*tert*-butyl dicarbonate (1.0 equiv.) under rapid stirring at room temperature. The reaction was monitored by TLC (diethyl ether/*n*-hexane, 1:1) until all the reactant had been consumed. Evaporation of the solvent at reduced pressure gave a residue that was partitioned between diethyl ether (100 mL) and $KHSO_4$ (30 mL, 1 mol dm^{-3}). The organic phase was thoroughly washed with $KHSO_4$ (1 mol dm^{-3}), $NaHCO_3$ (1 mol dm^{-3}) and saturated brine (2 × 30 mL, each), and dried with $MgSO_4$. Removal of the solvent afforded Tos-L-Ala-L-Ser(*O*-Boc)-OMe (**10b**) (0.378 g, 85%) as a white solid. M.p. 114.5–116.5 °C (from diethyl ether/petroleum ether). ^{1}H NMR ($CDCl_3$): δ = 7.74 (d, J = 8.4 Hz, 2 H, ArH), 7.29 (d, J = 8.4 Hz, 2 H, ArH), 6.88 (br. d, J = 7.8 Hz, 1 H, NH), 5.44 (br. d, J = 7.8 Hz, 1 H, NH), 4.68–4.63 (m, 1 H, αCH Ser), 4.40 (dd, J = 11.3, J = 3.9 Hz, 1 H, βCH_2 Ser), 4.10 (dd, J = 11.3, J = 3.6 Hz, 1 H, βCH_2 Ser), 3.91–3.85 (m, 1 H, αCH Ala), 3.76 (s, 3 H, CH_3 CO_2Me), 2.41 (s, 3 H, CH_3 Tos), 1.48 (s, 9 H, CH_3 Boc), 1.31 (d, J = 6.6 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 171.31 (C=O), 169.14 (C=O), 152.98 (C=O), 143.80 (C), 136.58 (C), 129.74 (CH), 127.22 (CH), 80.05 [$C(CH_3)_3$], 65.62 (βCH_2 Ser), 52.92 (OCH_3), 52.28 (αCH Ala), 51.86 (αCH Ser), 27.61 [C(CH_3)$_3$], 21.47 (CH_3 Tos), 19.54 (βCH_3 Ala) ppm. $C_{19}H_{28}N_2O_8S$ (444.50): calcd. C 51.34, H 6.35, N 6.30, S 7.21; found C 51.77, H 6.28, N 6.56, S 7.39.

Boc-Gly-L-Thr(*O*-Boc)-OMe (10h): The procedure described above was used substituting compound **7h** (5 mmol, 1.38 g) for **7b** to give **10h** as a white solid (1.54 g, 79%). M.p. 101.0–102.5 °C (from ethyl acetate/*n*-hexane) ^{1}H NMR ($CDCl_3$): δ = 6.64 (d, J = 7.5 Hz, 1 H, NH), 5.30–4.26 (m, 1 H, βCH), 5.12 (br. s, 1 H, NH), 4.79 (dd, J = 2.4, J = 9.3 Hz, 1 H, αCH), 3.91–3.86 (m, 2 H, CH_2 Gly), 3.75 (s, 3 H, CH_3 CO_2Me), 1.48 (s, 9 H, CH_3 Boc), 1.47 (s, 9 H, CH_3 Boc), 1.30 (d, J = 6.3 Hz, 3 H, γCH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.44 (C=O), 155.84 (C=O), 152.97 (C=O), 82.92 [$C(CH_3)_3$], 80.20 [$C(CH_3)_3$], 65.91 (βCH_2), 52.87 (OCH_3), 51.71 (αCH), 44.06 (CH_2), 28.22 [C(CH_3)$_3$], 27.58 [C(CH_3)$_3$] ppm. $C_{17}H_{30}N_2O_8$ (390.43): calcd. C 52.30, H 7.74, N 7.18; found C 53.43, H 7.61, N 7.42.

Boc-Gly-L-Ser(*O*-Boc)-OMe (10i): The procedure described above was used substituting compound **7i** (5 mmol, 1.38 g) for **7b** to give **10i** (1.26 g, 67%) as a white solid. M.p. 71.5–73.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 6.95 (d, J = 7.5 Hz, 1H, NH), 5.23 (br. s, 1 H, NH), 4.85–4.80 (m, 1 H, CH Ser), 4.47 (dd, J = 11.4, J = 3.6 Hz, 1 H, CH_2 Ser), 4.31 (dd, J = 11.4, J = 3.3 Hz, 1 H, CH_2 Ser), 3.86–3.82 (m, 2 H, CH_2 Gly), 3.76 (s, 3 H, CH_3 CO_2Me), 1.45 (s, 18 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.44 (C=O), 155.84 (C=O), 152.97 (C=O), 82.92 [$C(CH_3)_3$], 80.20 [$C(CH_3)_3$], 65.91 (βCH_2 Ser), 52.87 (OCH_3), 51.71 (αCH Ser), 44.06 (CH_2 Gly), 28.22 [C(CH_3)$_3$], 27.58 [C(CH_3)$_3$] ppm. $C_{16}H_{28}N_2O_8$ (376.40): calcd. C 51.05, H 7.50, N 7.44; found C 51.35, H 7.12, N 7.52.

Synthesis of *N*-Acyldehydrodipeptide Esters 9h and 9i from *N*-Acyl-*O*-(*tert*-Butyloxycarbonyl)Dipeptide Esters

Boc-Gly-*Z*-ΔAbu-OMe (9h): TMG (2% in volume) was added to a solution of Boc-Gly-L-Thr(*O*-Boc)-OMe (**10h**) (2 mmol, 0.78 g) in acetonitrile (0.1 mol dm^{-3}) and stirring was continued and the reaction followed by TLC. When all the reactant had been consumed evaporation at reduced pressure gave a residue that was partitioned between diethyl ether (50 mL) and $KHSO_4$ (30 mL, 1 mol dm^{-3}). The organic phase was thoroughly washed with $KHSO_4$ (1 mol dm^{-3}), $NaHCO_3$ (1 mol dm^{-3}) and saturated brine (2 × 30 mL, each), and dried with $MgSO_4$. Removal of the solvent afforded **9h** (0.50 g, 92%).

Boc-Gly-ΔAla-OMe (9i): The procedure described above was used substituting compound **10i** (1 mmol, 0.376 g) for **10h** to give **9i** (0.168 g, 65%) as a white solid. M.p. 155.0–156.5 °C (from diethyl ether/petroleum ether). ^{1}H NMR ($CDCl_3$): δ = 8.32 (br. s, 1 H, NH), 6.61 (s, 1 H, CH_2 ΔAla), 5.93 (d, J = 1.5 Hz, 1 H, CH_2 ΔAla), 5.16 (br. s, 1 H, NH), 3.90 (d, J = 7.8 Hz, 2 H, CH_2 Gly), 3.85 (s, 3 H, CH_3 CO_2Me), 1.47 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 168.27 (C=O), 164.24 (C=O), 156.92 (C=O), 130.56 (C), 109.39 (CH_2), 80.05 [(CH_3)$_3$*C*], 52.98 (OCH_3), 45.16 (CH_2), 21.48 [(*C*H$_3$)$_3$C] ppm. $C_{11}H_{18}N_2O_5$ (258.27): calcd. C 51.15, H 7.02, N 10.85; found C 51.08, H 7.00, N 10.89.

One-Pot Synthesis of *N*-Acyldehydrodipeptide Esters 9b,f,h–l

Tos-L-Ala-ΔAla-OMe (9b): DMAP (0.1 equiv.) was added to a solution of Tos-L-Ala-L-Ser-OMe (**7b**) (5 mmol, 1.72 g) in dry acetonitrile (1 mol dm^{-3}) followed by di-*tert*-butyl dicarbonate (1.0 equiv.) under rapid stirring at room temperature. The reaction was monitored by TLC (diethyl ether/*n*-hexane, 1:1) until all the reactant had been consumed. Then TMG (2% in volume) was added, stirring was continued and the reaction followed by TLC. When all the reactant had been consumed evaporation at reduced pressure gave a residue that was partitioned between diethyl ether (50 mL) and $KHSO_4$ (30 mL, 1 mol dm^{-3}). The organic phase was thoroughly washed with $KHSO_4$ (1 mol dm^{-3}), $NaHCO_3$ (1 mol dm^{-3}) and saturated brine (2 × 30 mL, each), and dried with $MgSO_4$. Removal of the solvent afforded **9b** (1.21 g, 93%) as a white solid. M.p. 113.5–114.5 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.50 (s, 1 H, NH), 7.77 (d, J = 8.1 Hz, 2 H, ArH), 7.29 (d, J = 8.1 Hz, 2 H, ArH), 6.46 (s, 1 H, βCH$_2$), 5.86 (br. d, J = 1.5 Hz, 1 H, βCH$_2$), 5.63 (br. d, J = 7.5 Hz, 1 H, NH), 3.91–3.86 (m, 1 H, αCH Ala), 3.83 (s, 3 H, CH_3 CO_2Me), 2.41 (s, 3 H, CH_3 Tos), 1.31 (d, J = 6.6 Hz, 3 H, βCH$_3$ Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.18 (C=O), 164.03 (C=O), 143.99 (C), 136.20 (C), 130.55 (C), 129.86 (CH), 127.27 (CH), 109.51 (βCH$_2$), 53.02 (OCH_3), 53.01 (αCH Ala), 21.50 (CH_3 Tos), 18.86 (βCH$_3$ Ala) ppm. $C_{14}H_{18}N_2O_5S$ (326.37): calcd. C 51.52, H 5.56, N 8.58, S 9.82; found C 51.72, H 5.70, N 8.43, S 9.44.

Tos-Ala-Z-ΔPhe-OMe (9f): The procedure described above was used substituting compound **7f** (1 mmol, 0.420 g) for **7b** to give **9f** (0.309 g, 77%).

Boc-Gly-Z-ΔAbu-OMe (9h): The procedure described above was used substituting compound **7h** (1 mmol, 0.290 g) for **7b** to give **9h** (0.229 g, 84%).

Boc-Gly-ΔAla-OMe (9i): The procedure described above was used substituting compound **7i** (1 mmol, 0.376 g) for **7b** to give **9i** (0.152 g, 59%).

Boc-Gly-*Z*-ΔPhe-OMe (9j): The procedure described above was used substituting compound **7j** (1 mmol, 0.376 g) for **7b** to give **9j** (1.10 g, 82%) as a white solid. M.p. 62.5–64.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.03 (br. s, 1 H, NH), 7.49–7.32 (m, 6 H, βCH ΔPhe + ArH), 5.50 (br. s, 1 H, NH), 3.92 (d, J = 3.6 Hz, 2 H, CH_2), 3.79 (s, 3 H, CH_3 CO_2Me), 1.42 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 168.65 (C=O), 165.44 (C=O), 156.14 (C=O), 133.28 (C), 129.75 (CH), 129.54 (CH), 128.58 (CH), 123.64 (C), 80.24 [(CH_3)$_3$*C*], 52.59 (OCH_3), 44.50 (CH_2), 28.19 [(*C*H$_3$)$_3$C] ppm. $C_{17}H_{22}N_2O_5$ (334.37): calcd. C 61.07, H 6.63, N 8.38; found C 60.83, H 6.74, N 8.65.

Z-Gly-ΔAla-OMe (9l): The procedure described above was used substituting compound **7l** (1 mmol, 0.310 g) for **7b** to give **9l** (0.178 g, 61%) as a white solid. M.p. 74.0–74.5 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.26 (br. s, 1 H, NH), 7.35–7.31 (m, 5 H, ArH), 6.60 (s, 1 H, βCH$_2$ ΔAla), 5.92 (d, J = 1.2 Hz, 1 H, βCH$_2$ ΔAla), 5.60 (br. s, 1 H, NH), 5.15 (s, 2 H, CH_2 Z), 3.97 (d, J = 5.4 Hz, 2 H, CH_2 Gly), 3.83 (s, 3 H, CH_3 CO_2Me) ppm. ^{13}C NMR ($CDCl_3$): δ = 167.76 (C=O), 164.21 (C=O), 156.59 (C=O), 135.99 (C), 130.46 (C), 128.50 (CH), 128.20 (CH), 128.07 (CH), 109.55 (CH_2), 67.29 (CH_2), 53.00 (OCH_3), 45.26 (CH_2) ppm. $C_{13}H_{16}N_2O_6$ (296.28): calcd. C 57.53, H 5.52, N 9.58; found C 57.44, H 5.47, N 9.66.

Synthesis of Piperazine Derivatives 11a,c

1-*tert*-Butyl 2-Methyl 6-Oxo-4-(4-tolylsulfonyl)piperazine-1,2-dicarboxylate (11a): The procedure described above for the preparation of **9b** was used substituting compound **7a** (1 mmol, 0.376 g) for **7b** to give **11a** (0.231 g, 56%) as a white solid. M.p. 113.0–114.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.64 (d, J = 8.1 Hz, 2 H, ArH), 7.36 (d, J = 8.1 Hz, 2 H, ArH), 4.80 (t, J = 3.6 Hz, 1 H, CH), 4.15–4.10 (m, 2 H, 2CH$_2$), 3.79 (s, 3 H, CH_3 CO_2Me), 3.46 (d, J = 15.9 Hz, 1 H, CH_2), 2.99 (dd, J = 12.6, J = 3.6 Hz, 1 H, CH_2), 2.44 (s, 3 H, CH_3 Tos), 1.48 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 168.88 (C=O), 163.41 (C=O), 150.59 (C=O), 144.80 (C), 131.67 (C), 130.05 (CH), 127.79 (CH), 84.90 [*C*(CH$_3$)$_3$], 57.11 (CH), 53.15 (OCH_3), 50.00 (CH_2), 45.48 (CH_2), 27.73 [C(*C*H$_3$)$_3$], 21.52 (CH_3 Tos) ppm. $C_{18}H_{24}N_2O_7S$ (412.46): calcd. C 52.42, H 5.86, N 6.79, S 7.77; found C 52.36, H 6.00, N 6.81, S 7.68.

1-*tert*-Butyl 2-Methyl 3-Methyl-6-oxo-4-(4-tolylsulfonyl)piperazine-1,2-dicarboxylate (11c): The procedure described above was used substituting compound **7c** (1 mmol, 0.376 g) for **7b** to give **11c** (0.222 g, 52%) as a white solid. M.p. 134.0–135.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 7.64 (d, J = 8.1 Hz, 2 H, ArH), 7.31 (d, J = 8.1 Hz, 2 H, ArH), 4.69 (qd, J = 6.9, J = 2.1 Hz, 1 H, CH), 4.60 (d, J = 2.1 Hz, 1 H, CH), 4.12 (d, J = 17.4 Hz, 1 H, CH_2), 3.80 (d, J = 17.4 Hz, 1 H, CH_2), 3.63 (s, 3 H, CH_3 CO_2Me), 2.42 (s, 3 H, CH_3 Tos), 1.49 (s, 9 H, CH_3 Boc), 1.20 (d, J = 6.9 Hz, 3 H, CH_3) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.14 (C=O), 163.53 (C=O), 151.09 (C=O), 144.24 (C), 135.37 (C), 129.86 (CH), 127.25 (CH), 84.90 [*C*(CH$_3$)$_3$], 62.62 (CH), 52.90 (OCH_3), 49.82 (CH_2), 45.75 (CH_2), 27.73 [C(*C*H$_3$)$_3$], 21.47 (CH_3 Tos), 15.19 (CH_3) ppm. $C_{19}H_{26}N_2O_7S$ (426.48): calcd. C 53.51, H 6.14, N 6.57, S 7.52; found C 53.56, H 6.26, N 6.39, S 7.29.

Synthesis of the Methyl Esters of *N*-Protected β-Brominated Dehydropeptides 12g and 13h,j

Boc-Ala-ΔAla(β-Br,Br)-OMe (12g): The same procedure described for the preparation of **4b** was followed substituting **9g** (1 mmol, 0.272 g) for **3b** to give **12g** (0.327 g, 76%) as an oil. ^{1}H NMR ($CDCl_3$): δ = 8.60 (br. s, 1 H, NH ΔAla), 5.04 (d, J = 6.0 Hz, 1 H, NH), 4.28 (br. t, J = 5.1 Hz, 1 H, CH Ala), 3.85 (s, 3 H, CH_3 CO_2Me), 1.45 (s, 9 H, CH_3 Boc), 1.36 (d, J = 6.9 Hz, 3 H, βCH$_3$ Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 169.93 (C=O), 162.56 (C=O), 156.03 (C=O), 132.27 (C), 85.47 (C), 81.00 [*C*(CH$_3$)$_3$], 53.00 (OCH_3), 49.46 (αCH), 28.25 [C(*C*H$_3$)$_3$], 16.49 (βCH$_3$) ppm. $C_{12}H_{18}Br_2N_2O_5$ (430.09): calcd. C 33.51, H 4.22, N 6.51; found C 33.77, H 4.36, N 6.39.

Boc-Gly-ΔAbu(β-Br)-OMe (13h): The same procedure described for the preparation of **5f** was followed substituting **9h** (1 mmol, 0.272 g) for **3f** to give (*E*)- and (*Z*)-**13h** as a 1:1 *E*/*Z* mixture (0.316 g, 90%). The diastereomers were separated by column chromatography using a solvent gradient of neat petroleum ether to 40% diethyl ether/petroleum ether. (*E*)-**13h**: M.p. 93.0–95.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.11 (br. s, 1 H, NH ΔAbu), 5.37 (br. t, J = 5.1 Hz, 1 H, NH Gly), 3.86 (d, J = 6.0 Hz, 2 H, CH_2), 3.81 (s, 3 H, CH_3 CO_2Me), 2.38 (s, 3 H, γCH$_3$), 1.46 (s, 9 H, CH_3 Boc) ppm. ^{13}C NMR ($CDCl_3$): δ = 168.10 (C=O),

164.24 (C=O), 156.53 (C=O), 125.66 (C), 122.82 (C), 80.73 [*C*(CH$_3$)$_3$], 52.49 (OCH$_3$), 44.33 (CH$_2$), 28.21 (CH$_3$ Boc), 25.61 (γCH$_3$) ppm. $C_{12}H_{19}BrN_2O_5$ (351.19): calcd. C 41.04, H 5.45, N 7.98; found C 41.52, H 5.37, N 7.98. (*Z*)-**13h**: M.p. 83.0–85.0 °C (from diethyl ether/*n*-hexane). ^{1}H NMR (CDCl$_3$): δ = 7.92 (br. s, 1 H, NH ΔAbu), 5.27 (s, 1 H, NH Gly), 3.88 (d, *J* = 6.0 Hz, 2 H, CH$_2$), 3.80 (s, 3 H, CH$_3$ CO$_2$Me), 2.57 (s, 3 H, γCH$_3$), 1.46 (s, 9 H, CH$_3$ Boc) ppm. ^{13}C NMR (CDCl$_3$): δ = 167.94 (C=O), 162.84 (C=O), 156.18 (C=O), 126.51 (C), 124.88 (C), 80.66 [*C*(CH$_3$)$_3$], 52.63 (OCH$_3$), 44.37 (CH$_2$), 28.24 [C(*C*H$_3$)$_3$], 24.70 (γCH$_3$) ppm. $C_{12}H_{19}BrN_2O_5$ (351.19): calcd. C 41.04, H 5.45, N 7.98; found C 40.93, H 5.40, N 8.05.

Boc-Gly-ΔPhe(β-Br)-OMe (13j): The same procedure described for the preparation of **5f** was followed substituting **9j** (1 mmol, 0.344 g) for **3f** to give **13j** as a 1:1 *E*/*Z* mixture (0.359 g, 87%) that could not be separated by column chromatography. ^{1}H NMR (CDCl$_3$): δ = 8.28 (s, 1 H, NH ΔPhe), 7.90 (s, 1 H, NH ΔPhe), 7.41 (br. s, 5 H, ArH), 7.36 (br. s, 5 H, ArH), 5.36 (br. t, *J* = 5.7 Hz, 1 H, NH Gly), 5.16 (br. s, 1 H, NH Gly), 3.93 (d, *J* = 5.7 Hz, 2 H, CH$_2$), 3.90 (s, 3 H, CH$_3$ CO$_2$Me), 3.72 (d, *J* = 6.0 Hz, 2 H, CH$_2$), 3.51 (s, 3 H, CH$_3$ CO$_2$Me), 1.48 (s, 9 H, CH$_3$ Boc), 1.34 (s, 9 H, CH$_3$ Boc) ppm. ^{13}C NMR (CDCl$_3$): δ = 167.98 (C=O), 167.27 (C=O), 164.42 (C=O), 163.33 (C=O), 156.26 (C=O), 155.98 (C=O), 137.00 (C), 136.15 (C), 129.68 (CH), 129.40 (CH), 128.98 (CH), 128.83 (CH), 128.51 (C), 128.33 (C), 128.24 (CH), 127.53 (C), 125.88 (C), 80.85 [*C*(CH$_3$)$_3$], 80.61 [*C*(CH$_3$)$_3$], 52.72 (OCH$_3$), 52.56 (OCH$_3$), 44.53 (CH$_2$), 44.13 (CH$_2$), 28.27 [C(*C*H$_3$)$_3$], 28.14 [C(*C*H$_3$)$_3$] ppm. $C_{17}H_{21}BrN_2O_5$ (413.26): calcd. C 49.41, H 5.12, N 6.78; found C 49.35, H 5.19, N 7.00.

Synthesis of 1-(4-Tolylsulfonyl)imidazolidin-4-one Derivatives 14a–f,k

Methyl 2-(Bromomethyl)-4-oxo-1-(4-tolylsulfonyl)imidazolidine-2-carboxylate (14a): *N*-Bromosuccinimide (1.1 equiv., 0.55 mmol) was added to a solution of Tos-Gly-ΔAla-OMe (**9a**) (0.5 mmol) in dichloromethane (0.1 mol dm^{-3}). The reaction was stirred at room temperature for 18 h and then triethylamine (1.1 equiv.) was added. After 4 h at room temperature, dichloromethane (25 mL) was added and the organic phase washed with water and brine (3 × 10 mL). After drying with MgSO$_4$ the extract was taken to dryness at reduced pressure to afford compound **14a** as a white solid (0.18 g, 92%). M.p. 150.0–151.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR (CDCl$_3$): δ = 7.75 (d, *J* = 8.1 Hz, 1 H, ArH), 7.35 (d, *J* = 8.1 Hz, 1 H, ArH), 7.27 (br. s, 1 H, NH), 4.23 (d, *J* = 12.0 Hz, 1 H, CH$_2$), 4.13 (d, *J* = 12.0 Hz, 1 H, CH$_2$), 4.06 (d, *J* = 14.1 Hz, 1 H, CH$_2$), 3.89 (d, *J* = 14.1 Hz, 1 H, CH$_2$), 3.77 (s, 3 H, CH$_3$ CO$_2$Me), 2.46 (s, 3 H, CH$_3$ Tos) ppm. ^{13}C NMR (CDCl$_3$): δ = 169.64 (C=O), 167.28 (C=O), 144.77 (C), 135.07 (C), 129.76 (CH), 127.50 (CH), 78.98 (C), 53.72 (OCH$_3$), 36.49 (CH$_2$), 21.57 (CH$_3$ Tos) ppm. MS (FAB): *m*/*z* (%) = 392.97 (26.21) and 390.97 (27.24) [M + 1]$^+$, 332.94 (12.46), 330.95 (12.41) [M – CO$_2$Me]$^+$. HRMS (FAB): calcd. for $C_{13}H_{15}BrN_2O_5S$ 389.9885 [M + 1]; found 390.9952. $C_{13}H_{15}BrN_2O_5S$ (391.24): calcd. C 39.91, H 3.86, N 7.16, S 8.20; found C 39.66, H 4.00, N 7.03, S 8.00.

Methyl 2-(Bromomethyl)-5-methyl-4-oxo-1-(4-tolylsulfonyl)imidazolidine-2-carboxylate (14b): The procedure described above was used substituting compound **9b** for **9a** to give **14b** (0.357 mg, 88%) as a diastereomeric mixture. ^{1}H NMR (CDCl$_3$): δ = 7.78 (d, *J* = 8.1 Hz, 2 H, ArH), 7.67 (s, 1 H, NH), 7.34 (d, *J* = 8.1 Hz, 2 H, ArH), 4.36 (q, *J* = 6.6 Hz, 1H, CH), 4.33 (d, *J* = 12.0 Hz, 1 H, CH$_2$), 4.19 (d, *J* = 12.3 Hz, 1 H, CH$_2$), 4.15 (d, *J* = 12.0 Hz, 1 H, CH$_2$), 4.12 (d, *J* = 12.3 Hz, 1 H, CH$_2$), 4.07 (q, *J* = 6.6 Hz, 1 H, CH), 3.82 (s, 3 H, CH$_3$ CO$_2$Me), 3.80 (s, 3 H, CH$_3$ CO$_2$Me), 2.45 (s, 3 H, CH$_3$ Tos), 1.58 (d, *J* = 6.6 Hz, 3 H, CH$_3$), 1.34 (d, *J* = 6.6 Hz, 3 H, CH$_3$) ppm. ^{13}C NMR (CDCl$_3$): δ = 173.06 (C=O), 172.69 (C=O), 168.07 (C=O), 167.57 (C=O), 144.73 (C), 144.57 (C), 136.68 (C), 136.36 (C), 129.73 (CH), 129.66 (CH), 127.88 (CH), 127.61 (CH), 78.70 (C), 78.06 (C), 57.12 (CH), 56.52 (CH), 53.92 (OCH$_3$), 53.64 (OCH$_3$), 37.19 (CH$_2$), 35.92 (CH$_2$), 21.58 (CH$_3$ Tos), 18.54 (CH$_3$), 17.09 (CH$_3$) ppm. $C_{14}H_{17}BrN_2O_5S$ (405.26): calcd. C 41.49, H 4.23, N 6.91, S 7.91; found C 41.95, H 4.37, N 6.99, S 7.76.

Methyl 2-(1-Bromoethyl)-4-oxo-1-(4-tolylsulfonyl)imidazolidine-2-carboxylate (14c): The procedure described above was used substituting compound **9c** for **9a** to give **14c** as a white solid (0.19 g, 94%). M.p. 161.0–162.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR (CDCl$_3$): δ = 7.66 (d, *J* = 8.4 Hz, 2 H, ArH), 7.37 (d, *J* = 8.4 Hz, 2 H, ArH), 6.41 (s, 1 H, NH), 5.32 (q, *J* = 7.5 Hz, 1 H, CH), 4.15 (d, *J* = 14.4 Hz, 1 H, CH$_2$), 3.91 (d, *J* = 14.4 Hz, 1 H, CH$_2$), 3.44 (s, 3 H, CH$_3$ CO$_2$Me), 2.46 (s, 3 H, CH$_3$ Tos), 1.86 (d, *J* = 7.5 Hz, 3 H, CH$_3$) ppm. ^{13}C NMR (CDCl$_3$): δ = 168.11 (C=O), 166.17 (C=O), 145.04 (C), 133.97 (C), 129.78 (CH), 127.69 (CH), 81.37 (C), 53.08 (OCH$_3$), 50.73 (CH$_2$), 48.80 (CH), 21.58 (CH$_3$ Tos), 18.74 (CH$_3$) ppm. MS (FAB): *m*/*z* (%) = 407.02 (40.70), 405.02 (40.99) [M + 1]$^+$, 346.99 (19.76), 344.99 (19.31) [M – CO$_2$Me]$^+$. HRMS (FAB): calcd. for $C_{14}H_{17}BrN_2O_5S$ 404.0042 [M + 1]; found 405.0105. $C_{14}H_{17}BrN_2O_5S$ (405.26): calcd. C 41.49, H 4.23, N 6.91, S 7.91; found C 41.64, H 4.39, N 6.91, S 8.00.

Methyl 2-(1-Bromoethyl)-5-methyl-4-oxo-1-(4-tolylsulfonyl)imidazolidine-2-carboxylate (14d): The procedure described above was used substituting compound **9d** for **9a** to give **14d** as a diastereomeric mixture (0.16 g, 74%). The diastereomers were isolated by column chromatography through silica using diethyl ether/petroleum ether as eluent. Diastereomer 1: m.p. 180.0–181.0 °C. ^{1}H NMR (CDCl$_3$): δ = 7.72 (d, *J* = 8.1 Hz, 2 H, ArH), 7.33 (d, *J* = 8.1 Hz, 2 H, ArH), 6.59 (br. s, 1 H, NH), 5.51 (q, *J* = 6.6 Hz, 1 H, CH), 4.37 (q, *J* = 6.9 Hz, 1 H, CH), 3.57 (s, 3 H, CH$_3$ CO$_2$Me), 2.45 (s, 3 H, CH$_3$ Tos), 1.84 (d, *J* = 6.6 Hz, 3 H, CH$_3$), 1.42 (d, *J* = 6.9 Hz, 3 H, CH$_3$) ppm. ^{13}C NMR (CDCl$_3$): δ = 170.95 (C=O), 167.40 (C=O), 144.62 (C), 137.47 (C), 129.24 (CH), 127.62 (CH), 81.17 (C), 58.59 (CH), 53.25 (OCH$_3$), 50.63 (CH), 21.56 (CH$_3$ Tos), 18.74 (CH$_3$), 17.94 (CH$_3$) ppm. $C_{15}H_{19}BrN_2O_5S$ (419.29): calcd. C 42.97, H 4.57, N 6.68, S 7.65; found C 43.01, H 4.62, N 6.66, S 7.47. Diastereomer 2: ^{1}H NMR (CDCl$_3$): δ = 7.62 (d, *J* = 8.1 Hz, 2 H, ArH), 7.36 (d, *J* = 8.1 Hz, 2 H, ArH), 6.54 (br. s, 1 H, NH), 5.22 (q, *J* = 6.6 Hz, 1 H, CH), 4.06 (q, *J* = 6.9 Hz, 1 H, CH), 3.39 (s, 3 H, CH$_3$ CO$_2$Me), 2.46 (s, 3 H, CH$_3$ Tos), 1.82 (d, *J* = 6.6 Hz, 3 H, CH$_3$), 1.69 (d, *J* = 6.9 Hz, 3 H, CH$_3$) ppm. ^{13}C NMR (CDCl$_3$): δ = 171.43 (C=O), 166.36 (C=O), 145.02 (C), 133.87 (C), 129.74 (CH), 127.91 (CH), 80.63 (C), 58.00 (CH), 48.91 (OCH$_3$), 52.98 (CH), 21.60 (CH$_3$ Tos), 19.36 (CH$_3$), 19.21 (CH$_3$) ppm. $C_{15}H_{19}BrN_2O_5S$ (419.29): calcd. C 42.97, H 4.57, N 6.68, S 7.65; found C 42.61, H 4.59, N 6.60, S 7.30.

Methyl 2-[Bromo(phenyl)methyl]-4-oxo-1-(4-tolylsulfonyl)imidazolidine-2-carboxylate (14e): The procedure described above was used substituting compound **9e** for **9a** to give **14e** as a diastereomeric mixture (0.20 g, 86%). ^{1}H NMR (CDCl$_3$): δ = 7.80–7.29 (m, 20 H, ArH + NH), 7.08 (s, 1 H, NH), 6.37 (s, 1 H, CH), 6.19 (s, 1 H, CH), 4.20 (d, *J* = 14.1 Hz, 1 H, CH$_2$), 3.98 (d, *J* = 14.1 Hz, 1 H, CH$_2$), 3.69 (d, *J* = 14.7 Hz, 1 H, CH$_2$), 3.60 (s, 3 H, CH$_3$ CO$_2$Me), 3.42 (s, 3 H, CH$_3$ CO$_2$Me), 3.12 (d, *J* = 14.7 Hz, 1 H, CH$_2$), 2.45 (s, 3 H, CH$_3$ Tos), 2.42 (s, 3 H, CH$_3$ Tos) ppm. ^{13}C NMR (CDCl$_3$): δ = 169.02 (C=O), 168.56 (C=O), 166.11 (C=O), 165.14 (C=O), 144.80 (C), 144.67 (C), 135.73 (C), 134.99 (C), 134.83 (C), 134.46 (C), 130.98 (CH), 130.04 (CH), 129.67 (CH), 129.42 (CH), 128.62

(CH), 128.46 (CH), 127.48 (CH), 127.34 (CH), 82.56 (C), 81.96 (C), 58.50 (CH), 53.47 (CH), 53.47 (OCH_3), 53.16 (OCH_3), 50.28 (CH_2), 50.19 (CH_2), 21.57 (CH_3 Tos), 21.56 (CH_3 Tos) ppm. MS FAB: *m*/*z* (%) =469.03 (16.38), 467.03 (15.96) $[M + 1]^+$, 297.05 (15.5) $[M – CHBrPh]^+$. HRMS (FAB): calcd. for $C_{19}H_{19}BrN_2O_5S$ 466.0198 [M + 1]; found 467.0288. $C_{19}H_{19}BrN_2O_5S$ (467.33): calcd. C 48.83, H 4.10, N 5.99, S 6.86; found C 48.76, H 4.38, N 6.05, S 6.71.

Methyl 2-[Bromo(phenyl)methyl]-5-methyl-4-oxo-1-(4-tolylsulfonyl)-imidazolidine-2-carboxylate (14f): The procedure described above was used substituting compound **9f** for **9a** to give **14f** as a diastereomeric mixture (0.22 g, 91%). The diastereomers were isolated by column chromatography through silica using diethyl ether/petroleum ether as eluent. Diastereomer 1 (0.041 g, 17%): m.p. 172.5–173.5 °C. ^{1}H NMR ($CDCl_3$): δ = 7.78–7.75 (m, 2 H, ArH Phe), 7.48–7.41 (m, 5 H, ArH Tos + ArH Phe), 7.24 (d, *J* = 8.1 Hz, 2 H, ArH Tos), 7.01 (s, 1 H, NH), 6.45 (s, 1 H, CH ΔPhe), 3.74 (s, 3 H, CH_3 CO_2Me), 3.15 (q, *J* = 14.7 Hz, 1 H, CH_2), 2.41 (s, 3 H, CH_3 Tos), 1.26 (d, *J* = 6.9 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 171.27 (C=O), 167.24 (C=O), 144.41 (C), 137.59 (C), 134.32 (C), 130.75 (CH), 129.68 (CH), 129.60 (CH), 128.59 (CH), 127.34 (CH), 81.51 (C), 57.96 (CHBr), 54.58 (αCH Ala), 53.66 (OCH_3), 21.50 (CH_3 Tos), 17.40 (CH_3) ppm. $C_{20}H_{21}BrN_2O_5S$ (481.36): calcd. C 49.90, H 4.40, N 5.82, S 6.66; found C 50.10, H 4.56, N 5.73, S 6.69. Mixture of diastereomers (0.118 g, 49%): ^{1}H NMR ($CDCl_3$): δ = 7.86 (d, *J* = 8.1 Hz, 2 H, ArH Tos), 7.80 (d, *J* = 8.1 Hz, 2 H, ArH Tos), 7.62–7.52 (4m, 5 H, ArH), 7.38–7.33 (m, 10 H, ArH), 6.64 (s, 1 H, CHBr), 6.61 (s, 1 H, NH), 6.42 (s, 1 H, NH), 6.16 (s, 1 H, CHBr), 4.43 (q, *J* = 6.9 Hz, 1 H, αCH Ala), 4.24 (q, *J* = 6.9 Hz, 1 H, αCH Ala), 3.47 (s, 3 H, CH_3 CO_2Me), 3.42 (s, 3 H, CH_3 CO_2Me), 2.46 (s, 3 H, CH_3 Tos), 2.45 (s, 3 H, CH_3 Tos), 1.69 (d, *J* = 6.9 Hz, 3 H, βCH_3 Ala), 1.46 (d, *J* = 6.9 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 172.17 (C=O), 171.56 (C=O), 165.96 (C=O), 165.56 (C=O), 144.90 (C), 144.38 (C), 137.90 (C), 135.89 (C), 135.37 (C), 134.79 (C), 130.56 (CH), 129.92 (CH), 129.63 (CH), 129.60 (CH), 129.56 (CH), 129.24 (CH), 128.86 (CH), 128.53 (CH), 128.17 (CH), 127.68 (CH), 82.55 (C), 81.20 (C), 58.87 (CHBr), 56.86 (αCH Ala), 53.21 (OCH_3), 53.12 (OCH_3), 21.63 (CH_3 Tos), 21.56 (CH_3 Tos), 18.36 (βCH_3 Ala), 18.33 (βCH_3 Ala) ppm. Diastereomer 2 (0.034 g, 14%): ^{1}H NMR ($CDCl_3$): δ = 7.68–7.63 (m, 2 H, ArH), 7.54 (d, *J* = 8.1 Hz, 2 H, ArH Tos), 7.42–7.39 (m, 3 H, ArH), 7.32 (d, *J* = 8.1 Hz, 2 H, ArH Tos), 6.80 (br. s, 1 H, NH), 6.13 (s, 1 H, CHBr), 3.89 (q, *J* = 6.9 Hz, 1 H, αCH Ala), 3.48 (s, 3 H, CH_3 CO_2Me), 2.44 (s, 3 H, CH_3 Tos), 0.68 (d, *J* = 6.9 Hz, 3 H, βCH_3 Ala) ppm. ^{13}C NMR ($CDCl_3$): δ = 171.12 (C=O), 166.23 (C=O), 144.83 (C), 134.71 (C), 134.54 (C), 130.84 (CH), 129.66 (CH), 129.47 (CH), 128.29 (CH), 127.69 (CH), 81.50 (C), 57.91 (αCH Ala), 54.35 (CHBr), 53.30 (OCH_3), 21.59 (CH_3 Tos), 18.17 (βCH_3 Ala) ppm. HRMS (FAB): calcd. for $C_{20}H_{22}BrN_2O_5S$ 480.0433 [M + 1]; found 481.0435.

Synthesis of the Tripeptide Tos-Gly-ΔAla-Gly-OMe (9k)

Tos-Gly-ΔAla-OH: NaOH (1 equiv., 1 mol dm^{-3}) was added to a solution of Tos-Gly-ΔAla-OMe (**9a**) (0.34 mmol) in dioxane (3 mL). The solution was stirred for 18 h at room temperature (the reaction was followed by TLC until no starting material was detected). The reaction mixture was acidified to pH 2–3 with $KHSO_4$ (1 mol dm^{-3}) and the solid formed filtered. Crystallization from ethyl acetate/*n*-hexane afforded Tos-Gly-ΔAla-OH (0.10 g, 98%) as a white solid. M.p. 159.5–161.0 °C. ^{1}H NMR (DMSO): δ = 13.60 (s, 1 H, COOH), 9.11 (s, 1 H, NH ΔAla), 8.16 (t, *J* = 6.3 Hz, 1 H, NH Gly), 7.68 (d, *J* = 8.1 Hz, 2 H, ArH), 7.38 (d, *J* = 8.1 Hz, 2 H, ArH), 6.27 (s, 1 H, CH_2 ΔAla), 5.70 (s, 1 H, CH_2 ΔAla), 3.58 (d, *J* = 6.3 Hz, 2 H, CH_2 Gly), 2.37 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR (DMSO): δ = 167.47 (C=O), 164.73 (C=O), 143.04 (C), 137.03 (C), 132.20 (C), 129.69 (CH), 126.70 (CH), 107.70 (βCH_2), 45.85 (CH_2), 21.01 (CH_3 Tos) ppm. $C_{12}H_{14}N_2O_5S$ (298.26): calcd. C 48.32, H 4.73, N 9.39, S 10.73; found C 48.09, H 4.86, N 9.20, S 10.69.

Tos-Gly-ΔAla-Gly-OMe (9k): HOBt (0.22 mmol, 0.034 mg) and DCC (0.22 mmol, 0.044 mg) were added to a solution of Tos-Gly-ΔAla-OH (0.20 mmol) in acetonitrile (5 mL) with vigorous stirring at 0 °C. After 15 min, HCl·H-Gly-OMe (0.2 mmol) and Et_3N (0.2 mmol, 0.03 mL) were added. The reaction was stirred for 18 h at room temperature. The urea was removed by filtration and the solvent removed at reduced pressure. The oily residue was dissolved in ethyl acetate (15 mL) and the solution washed with $KHSO_4$ (1 mol dm^{-3}), $NaHCO_3$ (1 mol dm^{-3}) and brine (3 × 5 mL, each). The organic layer was dried with $MgSO_4$ and the solvent removed at reduced pressure giving an oil which was purified by column chromatography with diethyl ether/petroleum ether (2:1). Compound **9k** was isolated as a white solid (0.053 g, 72%). M.p. 114.0–115.5 °C (from ethyl acetate/diethyl ether). ^{1}H NMR ($CDCl_3$): δ = 8.59 (s, 1 H, NH ΔAla), 7.76 (d, *J* = 8.4 Hz, 2 H, ArH), 7.31 (d, *J* = 8.4 Hz, 2 H, ArH), 6.83 (s, 1 H, NH Gly), 6.37 (s, 1 H, CH_2 ΔAla), 5.60 (s, 1 H, NH Gly), 5.40 (s, 1 H, CH_2 ΔAla), 4.12 (d, *J* = 5.4 Hz, 2 H, CH_2 Gly), 3.80 (s, 3 H, CH_3 CO_2Me), 3.70 (s, 2 H, CH_2 Gly), 2.42 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 170.22 (C=O), 167.04 (C=O), 163.94 (C=O), 143.97 (C), 135.72 (C), 133.29 (C), 129.86 (CH), 127.23 (CH), 104.41 (βCH_2), 52.59 (OCH_3), 46.36 (CH_2), 41.60 (CH_2), 21.50 (CH_3 Tos) ppm. $C_{15}H_{19}N_3O_6S$ (369.34): calcd. C 48.78, H 5.18, N 11.38, S 8.72; found C 48.93, H 5.27, N 11.40, S 8.72.

Methyl 2-[2-(Bromomethyl)]-4-oxo-1-(4-tolylsulfonyl)imidazolidine-2-carboxamidoacetate (14k): The procedure described above for the synthesis of **14a** was used substituting compound **9k** (0.1 mol) for **9a** to give **14k** as a white solid (0.036 g, 82%). M.p. 161.0–162.0 °C (from ethyl acetate/*n*-hexane). ^{1}H NMR ($CDCl_3$): δ = 8.36–8.22 (m, 1 H, NH), 8.20 (s, 1 H, NH), 7.74 (d, *J* = 7.8 Hz, 2 H, ArH), 7.35 (d, *J* = 7.8 Hz, 2 H, ArH), 4.42 (d, *J* = 12.3 Hz, 1 H, CH_2), 4.35 (dd, *J* = 7.5, *J* = 17.9 Hz, 1 H, CH_2), 4.06 (d, *J* = 12.3 Hz, 1 H, CH_2), 4.03 (d, *J* = 13.8 Hz, 1 H, CH_2), 3.93 (d, *J* = 13.8 Hz, 1 H, CH_2), 3.74 (s, 3 H, CH_3 CO_2Me), 3.55 (dd, *J* = 4.5, *J* = 17.9 Hz, 1 H, CH_2), 2.46 (s, 3 H, CH_3 Tos) ppm. ^{13}C NMR ($CDCl_3$): δ = 172.24 (C=O), 170.94 (C=O), 167.56 (C=O), 144.75 (C), 135.08 (C), 129.77 (CH), 127.53 (CH), 79.35 (C), 53.05 (OCH_3), 49.98 (CH_2), 41.00 (CH_2), 38.54 (CH_2), 21.65 (CH_3 Tos) ppm. $C_{15}H_{18}BrN_3O_6S$ (448.29): calcd. C 40.19, H 4.05, N 9.37, S 7.15; found C 40.01, H 4.16, N 9.39, S 7.03.

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