Stereoselective Synthesis of Pyrrolidines and Pyrrolizidines by Intramolecular Carbolithiation

Iain Coldham,* Richard Hufton, Kathy N. Price, Richard E. Rathmell, David J. Snowden, Graham P. Vennall

School of Chemistry, University of Exeter, Stocker Road, Exeter EX4 4QD, UK
Fax +44(1392)263434; E-mail: I.Coldham@exeter.ac.uk

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Abstract: Methods for the preparation of substituted homoallylic amines and their conversion to pyrrolidines or pyrrolizidines are described. *N*-Alkylation of a variety of homoallylic secondary amines with (tributylstannyl)methyl methanesulfonate and subsequent tin-lithium exchange, generates organolithium species that undergo intramolecular carbolithiation (anionic cyclization). High stereoselectivities in the cyclization, particularly for the formation of 2,4-disubstituted pyrrolidines, are obtained.

Key words: amines, carbanions, cyclizations, lithiation, heterocycles

The vast array of different structural arrangements within the alkaloid class of natural products, together with their diverse biological activity has fascinated scientists and prompted numerous synthetic efforts worldwide towards their preparation. Methods for the construction of simple pyrrolidines to complex polycyclic amines have been reported and allow the study of the chemical and biological properties of many alkaloids and their analogs.

In this paper we report some of our work on the preparation of substituted pyrrolidines and pyrrolizidines using intramolecular carbolithiation chemistry. Some representative pyrrolidine and pyrrolizidine alkaloids are shown in Figure 1. Many biologically active compounds, natural and synthetic, containing these ring systems are known and new methods to access such targets are of interest and importance, for example, in medicinal chemistry. The pyrrolidine and pyrrolizidine target compounds contain

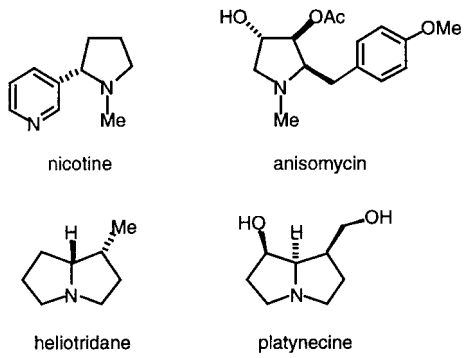

Figure 1 Some representative pyrrolidine and pyrrolizidine alkaloids

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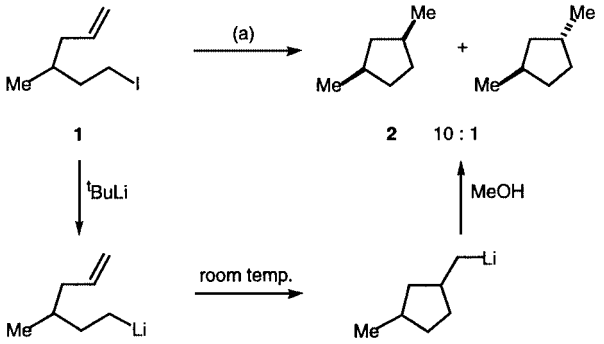
one or, commonly, more than one chiral center and therefore stereocontrolled methods for their preparation are required.

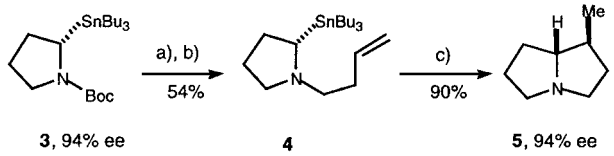
Intramolecular carbolithiation reactions refer to the cyclization of an organolithium species onto an unsaturated functional group, typically an alkene or alkyne. Extensive studies by Bailey and co-workers have established the chemistry as a highly effective method for the formation of, in particular, cyclopentane and cyclohexane ring systems.[1] The cyclization is a high yielding process and the initially formed cyclic organolithium species can be trapped by a variety of electrophiles to give functionalized products. Cyclization onto an alkene generates a product containing a new chiral centre. It was found that the use of a substrate, such as **1** (Scheme 1), containing a chiral centre, promoted a regioselective and stereoselective intramolecular carbolithiation reaction to provide predominantly the *cis*-1,3-disubstituted cyclopentane **2**.[2] The iodine-lithium exchange process occurs at low temperature and the mixture is allowed to warm to room temperature in order to effect cyclization. The predominance of the *cis*-product is explained by a preference for a chair-shaped transition state, in which the lithium atom coordinates to the alkene π-bond.[2]



Scheme 1 (a) *t*-BuLi (2.1 equiv), pentane–Et_2O (3:2), –78 °C to r.t.., 1 h, then MeOH

To make use of this chemistry for the synthesis of pyrrolidines and pyrrolizidines, a nitrogen atom must be located within the newly forming ring system. The position of the nitrogen atom and choice of functionality is crucial in order to allow successful formation of the organolithium species (and its precursor) and to avoid side reactions such as β-elimination. Early examples of this chemistry to give the pyrrolidine ring system using sulfur-lithium exchange

were reported by Broka and co-workers.[3] Generation of aryl- or vinyllithium species from the corresponding halides and cyclization to give cyclic amines is known.[4] Proton abstraction and anionic cyclization has also been reported.[5] A particularly useful approach centres on tin-lithium exchange for the formation of an α-amino-organolithium species that can undergo the intramolecular carbolithiation reaction.[6,7] The precursor α-amino-organostannanes can be prepared by a number of methods, such as alkylation of a secondary amine with iodomethyltrialkyltin[8] or (tributylstannyl)methyl methanesulfonate,[9] addition of a trialkyltin metal species to an iminium ion,[10] or addition of a trialkyltin chloride to an α-amino-organometallic species.[11] For example, the stannane **3** (Scheme 2) can be prepared with high optical purity in a single step from *N*-Boc-pyrrolidine, using asymmetric proton abstraction in the presence of (–)-sparteine and quench with tributyltin chloride.[12] Transformation of the stannane **3** to the stannane **4** and tin-lithium exchange effects a stereoselective intramolecular carbolithiation reaction to give the alkaloid (+)-pseudoheliotridane (**5**) as a single diastereomer with no loss of optical purity.[13]



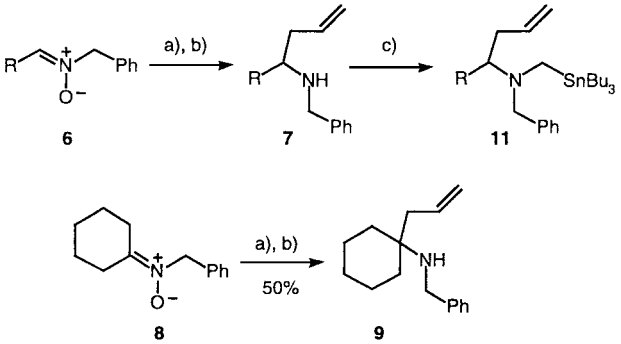
3, 94% ee **4** **5**, 94% ee

Scheme 2 (a) β-Bromocatechol borane, CH_2Cl_2, then but-3-enoyl chloride; (b) AlH_3, Et_2O; (c) BuLi, hexane–Et_2O (10:1), r. t., 1 h, then MeOH

The stannane **4** has a chiral centre at the projected lithium-bearing carbon atom. The presence of a substituent at other locations within the newly forming pyrrolidine ring can also have an influence on the stereoselectivity of the cyclization. To investigate this stereoselectivity, we have prepared a variety of substituted α-amino-organostannanes and report herein the results of their cyclization.[14]

Initial work focused on the formation of 2-substituted homoallylic secondary amines. Alkylation of these amines with iodomethyltributyltin was expected[6a] to provide the α-amino-organostannanes required for the investigation of the stereoselectivity in the intramolecular carbolithiation reaction. A versatile synthesis of the homoallylic amines was required that would allow the preparation of a variety of 2-substituted derivatives. The approach adopted is shown in Scheme 3, using allyl Grignard addition to the nitrones **6**.[15] Reduction of the product hydroxylamines using zinc and acetic acid provided the homoallylic amines **7**. This chemistry could also be applied to the nitrone **8**, to give the homoallylic amine **9**.

Attempted alkylation of the amines **7** with iodomethyltributyltin[8] gave only recovered starting amine under a variety of conditions. This contrasts with the substrate **7** (R = H) in which alkylation proceeds smoothly,[6a] suggesting that substitution at the carbon α to the nitrogen atom slows the rate of *N*-alkylation due to steric hindrance. An alternative procedure was therefore required in order to provide the stannanes **11**. Treatment of secondary amines with formaldehyde and benzotriazole, followed by displacement of the benzotriazole group with tributyltin-lithium has been reported as an effective method for the synthesis of substituted α-amino-organostannanes.[10c,d] However, condensation of the amine **7** (R = Me) with paraformaldehyde and benzotriazole in toluene gave a mixture (58%, 1:1) of the recovered amine **7** (R = Me) and the amine **7** (R = H). The product **7** (R = H) must arise from the intermediate iminium ion, which can undergo a [3,3] aza-Cope rearrangement, followed by hydrolysis of the new iminium ion. No products resulting from trapping of either iminium ion with benzotriazole were observed. The problem was solved using the more reactive alkylating agent (tributylstannyl)methyl methanesulfonate (**10**),[9] which can be prepared from the corresponding alcohol and methanesulfonic anhydride. Alkylation was sluggish but proceeded on warming to give the amines **11** in reasonable to poor yields (Table 1). The yield of the alkylated product reduces with the increasing size of the α-substituent. This is illustrated further on attempted alkylation of the more hindered amine **9**, which gave the corresponding α-amino-organostannane in very poor yield (8%).



6 **7** **11**

8 **9**

Scheme 3 (a) Mg, allyl bromide, Et_2O, THF, r.t., 4 h, then NH_4Cl; (b) Zn, AcOH–H_2O (1:1), ultrasound, 4 h, r.t.; (c) $MsOCH_2SnBu_3$ (**10**), MeCN, K_2CO_3 or *i*-Pr_2NEt, 55 °C, 2 d

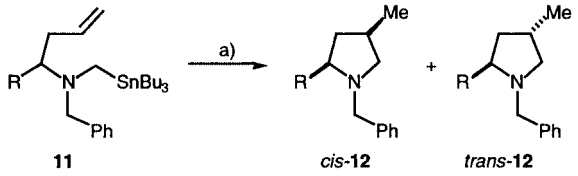
Table 1 Preparation of the Stannanes **11**

Nitrone	R	Yield **7** (%)	Yield **11** (%)
6a	Me	80	57
6b	*n*-Bu	61	45
6c	*i*-Pr	84	14

The stannanes **11** were treated with butyllithium to effect tin-lithium exchange and intramolecular carbolithiation (Scheme 4). Using THF as the solvent at low temperature, the stannane **11a** (R = Me) gave, after quenching with MeOH, exclusively the *cis*-2,4-disubstituted pyrrolidine **12a** (46%), confirmed by NOE studies. This result con-

forms with those of Bailey[2] and Broka,[3] in which the major product has the substituents *cis* to one another as expected from a chair-shaped transition state (Figure 2). To our surprise, the stannanes **11b** and **11c** did not transmetallate in THF, even on warming. The increased steric bulk of the larger R substituent may be hindering the formation of the intermediate stannate complex.

We have found previously[6] that non-polar solvents give enhanced yields of the pyrrolidine products, and indeed, the use of hexane–Et_2O gave the desired pyrrolidines **12** in good yield (Table 2). In this solvent system, transmetallation and cyclization was successful for all the stannanes **11a**–**c**. Transmetallation occurs at room temperature and may be taking place by a mechanism that is different from that in THF, and which involves a concerted process.[16] At this temperature, some of the pyrrolidines *trans*-**12** were obtained, although the *cis*-isomer remained the major product.



Scheme 4 (a) BuLi, THF or hexane–Et_2O (10:1), –78 °C to r.t., 5 h then MeOH

Table 2 Cyclization of the Stannanes **11** in Hexane–Et_2O (10:1)

Stannane	R	Yield **12** (%)	*cis*/*trans*
11a	Me	78	7 :1
11b	Bu	50	6 : 1
11c	*i*-Pr	74	6 : 1

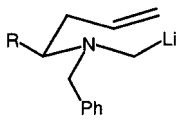
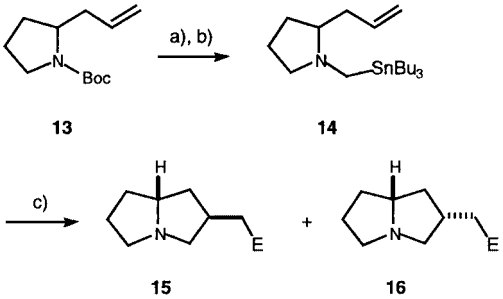


Figure 2 Chair-shaped transition state of the intermediate organo lithium from **11**

The chemistry outlined above allows an efficient and stereocontrolled access to substituted pyrrolidines. We were interested in extending this methodology to the preparation of substituted pyrrolizidines and investigating the possibility of trapping the intermediate organolithium species with a variety of different electrophiles. Scheme 5 outlines our approach to the pyrrolizidine ring system using the stannane **14**, prepared from *N*-Boc-2-allylpyrrolidine **13**.[17] Acidic hydrolysis of the *N*-Boc group gave the known, volatile, 2-allyl-pyrrolidine,[18] which was alkylated with (tributylstannyl)methyl methanesulfonate (**10**).

The stannane **14** was treated with butyllithium in hexane–Et_2O to effect transmetallation and cyclization. On trapping the resulting organolithium species with methanol, the pyrrolizidines **15** and **16** (E = H) were isolated as their picrate salts, as an inseparable (3:1) mixture of isomers. The intermediate organolithium species was trapped with different electrophiles to give different substituted pyrrolizidines (Table 3). In each case the products **15** and **16** (picrate salts) were isolated as a mixture (3:1) of diastereomers. Attempts to determine (by NMR) the identity of the major diastereomer were unsuccessful. The preference for a chair-shaped transition state, with a *cis*-fused azabicyclo[3.3.0]octane ring system, suggests that the major product would be the pyrrolizidine **15**, arising from the transition state depicted in Figure 3. X-Ray analysis of the picrate salt of the mixture of pyrrolizidines **15** and **16** (E = H), indicate that the major component is indeed the pyrrolizidine **15**.[19]



Scheme 5 (a) CF_3CO_2H, CH_2Cl_2, r.t.; (b) **10**, MeCN, *i*-Pr_2NEt, r.t.; (c) BuLi, hexane–Et_2O (9:1), –78 °C to r.t., 4 h, then E^+, then picric acid, EtOH

Table 3 Cyclization of the Stannane **14**

Entry	E^+	E	Yield **15** + **16** (%)
1	MeOH	H	81
2	TMSCl	$SiMe_3$	66
3	Bu_3SnCl	$SnBu_3$	67
4	allyl bromide	$CH_2CH{=}CH_2$	55
5	$Ph_2C{=}O$	$C(OH)Ph_2$	60

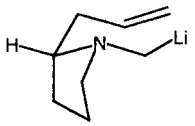
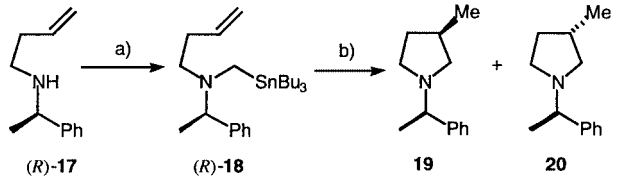


Figure 3 Chair-shaped transition state of the intermediate lithium salt from **14**

The successful synthesis of pyrrolidines and pyrrolizidines by intramolecular carbolithiation of chiral (racemic) organolithium compounds derived from the stannanes **11** and **14**, led us to investigate the influence of a chiral auxiliary attached to the nitrogen atom.[20] Alkylation of (*R*)- or (*S*)-α-methylbenzylamine with but-3-enyl bromide, followed by (tributylstannyl)methyl methanesulfonate (**10**), gave the stannanes (*R*)- or (*S*)-**18**

(Scheme 6). Transmetallation with butyllithium effected intramolecular carbolithiation to give, after quenching with methanol, the pyrrolidines **19** and **20** (Table 4). In the non-polar hexane–Et_2O solvent system at 0 °C, an equal mixture (determined by ^1H NMR spectroscopy) of the diastereomeric pyrrolidines **19** and **20** was formed (entry 1). However, in THF at –78 °C, a 3:1 mixture in favour of the pyrrolidine **19** was produced, as determined by hydrogenolysis of the α-methylbenzyl group and comparison of the sign of optical rotation with the known (*R*)-3-methylpyrrolidine.[21] Altering the conditions or amount of reagents gave no significant enhancement in the ratio of products. Addition of (–)-sparteine, did, however, give a small improvement when using the enantiomer (*R*)-**18** (entry 3). However, no influence from (–)-sparteine in Et_2O (stannane **18** in hexane–Et_2O) was observed (entry 4) and using (–)-sparteine in THF gave results analogous to those in THF alone (transmetallation and cyclization at –78 °C, entry 5). Addition of (–)-sparteine to the enantiomer (*S*)-**18** resulted in a mis-matched case and significant reduction in diastereoselectivity (entry 6). These results suggest that (–)-sparteine is coordinated to the organolithium species and can play a part in influencing the stereochemical outcome.



Scheme 6 (a) **10**, MeCN, *i*-Pr_2NEt, r.t.; (b) BuLi, solvent, –78 °C to r.t., then MeOH

Table 4 Cyclization of the Stannane **18**

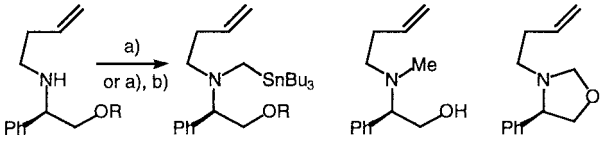
Entry	**18**	Conditions	Yield **19** + **20** (%)	Ratio **19**/**20**
1	(*R*)-	hexane–Et_2O (10:1), 0 °C	73	50:50
2	(*R*)-	THF, –78 °C	78	74:26
3	(*R*)-	THF (–)-sparteine/THF, –78 °C	74	79:21
4	(*R*)-	hexane–Et_2O (10:1), (–)-sparteine/Et_2O, 0 °C	86	50:50
5	(*R*)-	hexane–Et_2O (10:1), (–)-sparteine/THF, –78 °C	79	77:23
6	(*S*)-	hexane–Et_2O (10:1), (–)-sparteine/THF, –78 °C	73	45:55

The marked stereochemical influence of the α-methylbenzyl group led us to consider preparing a substrate that would promote greater stereoselectivity in the cyclization, possibly through a more rigid transition state. The ability of organolithium species to coordinate to nitrogen or oxygen lone pairs is known and the presence of a heteroatom on the chiral auxiliary that would allow such coordination could hold the chiral auxiliary in a cyclic arrangement. We therefore prepared the stannanes **22** (R = H and R = Me) from the amine **21** (R = H) itself derived from (*R*)-phenylglycinol (Scheme 7).[22]

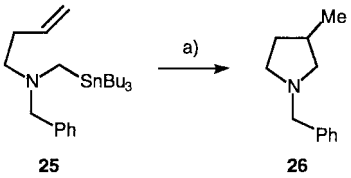
Addition of butyllithium to the stannane **22** (R = H) in the solvent THF resulted in tin-lithium exchange, but no pyrrolidine products were isolated. A mixture of the four products **22** (R = H, 18%), **21** (R = H, 18%), protodestannylated compound **23** (39%) and the oxazolidine **24** (20%) were obtained. In the less polar hexane–Et_2O solvent system, transmetallation was very sluggish and recovered starting material **22** (R = H) was isolated even after several hours at room temperature. It is likely that butyllithium abstracts a proton first from the alcohol group and that the subsequent tin-lithium exchange then requires a polar solvent system. The origin of the oxazolidine **24** is not clear.

Addition of butyllithium to the stannane **22** (R = Me) effected transmetallation in either THF or hexane–Et_2O. In both cases a complex mixture of products was obtained and none of the desired pyrrolidine product was isolated. It appears, therefore, that for this type of substrate at least, the presence of an oxygen atom lone pair to coordinate to the lithium atom inhibits the intramolecular carbolithiation reaction.

Finally, we investigated the influence of (–)-sparteine alone to promote asymmetric induction in the intramolecular carbolithiation reaction.[23] The stannane **25**[6a] in THF or hexane–Et_2O was treated with butyllithium/(–)-sparteine complex to promote transmetallation and cyclization to *N*-benzyl-3-methylpyrrolidine **26** (Scheme 8). Good yields of the pyrrolidine **26** were obtained, but with low levels of optical purity (Table 5). Over a range of conditions, the enantioselectivity of the cyclization remained fairly constant at approximately 28% ee. The selectivity was measured by ^1H NMR spectroscopy using the Pirkle chiral solvating agent.[24]



Scheme 7 (a) **10**, MeCN, *i*-Pr_2NEt, r.t.; (b) NaH, MeI, THF, r.t.



Scheme 8 (a) (–)-sparteine, BuLi, solvent, –78 °C to r.t., then MeOH

Table 5 Cyclization of the Stannane **25** with (–)-Sparteine in THF

Entry	Conditions	Yield 26 (%)	Ratio 26 (ee)
1	THF, –78 °C	74	63:37 (26)
2	THF, –78 °C[a]	74	64:36 (28)
3	hexane–Et_2O (10:1), –78 °C	84	64:36 (28)
4	hexane–Et_2O (10:1), 0 °C[b]	82	64:36 (28)

[a] Inverse addition.
[b] (–)-Sparteine in Et_2O.

In conclusion, the intramolecular carbolithiation reaction can be used as an efficient and stereoselective approach to substituted pyrrolidines and pyrrolizidines. These targets are present in a wide range of alkaloid and other natural product structures and this chemistry therefore provides a convenient method for their preparation.

Experimental information concerning solvents, spectroscopic equipment, etc. has been reported previously.[25] Light petroleum used had bp 40–60 °C.

Homoallylic Amines 7a–c, 9; General Procedure
The nitrone **6** or **8** (6.3 mmol) in anhyd THF (15 mL) was added to allylmagnesium bromide, prepared from allyl bromide (2.44 g, 20.2 mmol) and Mg turnings (476 mg, 19.6 mmol) in Et_2O (20 mL), under N_2 at r.t. After 2 h, the mixture was cooled to 0 °C and was quenched cautiously with sat. aq NH_4Cl solution (50 mL), extracted into CH_2Cl_2 (3 × 50 mL), dried ($MgSO_4$) and evaporated. The residue was purified by column chromatography [silica gel, light petroleum–EtOAc (10:1)] to give the intermediate hydroxylamine.

Spectroscopic data for hydroxylamines leading to amines **7a–b** and **9** are given below. Spectroscopic data for hydroxylamine leading to amine **7c** agree with that reported.[15c]

Zinc dust (1.18 g, 18 mmol) was added to the hydroxylamine (3.7 mmol) in glacial AcOH (5 mL) and H_2O (5 mL) at r.t. and the mixture was subjected to sonication. After 3 h, the mixture was filtered, basified to pH ~10 with NaOH (2 M), extracted with CH_2Cl_2 (3 × 50 mL), dried ($MgSO_4$) and evaporated. The residue could be purified by distillation under reduced pressure to give the homoallylic amine **7** or **9**, as an oil.

Spectroscopic data for amines **7** and **9** agree with that reported.[26]

Hydroxylamine from 6a and Allylmagnesium Bromide
Mp 62–64 °C.

IR (film): ν = 3200 (OH), 3075 (CH), 3030 (CH), 2970 (CH), 1600 cm^{-1} (Ph).

^{1}H NMR ($CDCl_3$): δ = 1.12 (3 H, d, *J* = 6.5 Hz, CH_3), 2.08–2.20 (1 H, m, C*H*CHMe), 2.43–2.54 (1 H, m, C*H*CHMe), 2.78–2.90 (1 H, m, C*H*Me), 3.78 (2 H, ABq, *J* = 13.0 Hz, CH_2Ph), 5.04 (1 H, d, *J* = 10.0 Hz, CH=C), 5.06 (1 H, d, *J* = 17.0 Hz, CH=C), 5.58 (1 H, br s, OH), 5.82 (1 H, dddd, *J* = 17.0, 10.0, 7.5, 6.5 Hz, CH=C), 7.21–7.42 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 14.19, 37.82, 59.71, 60.94, 116.19, 127.18, 128.26, 129.52, 136.38, 138.25.

HRMS: *m/z* Found M^+, 191.1311. $C_{12}H_{17}NO$ requires M, 191.1310.

MS: *m/z* (%) = 191 (0.1, M^+), 150 (28, M – C_3H_5), 91 (100, CH_2Ph).

Hydroxylamine from 6b and Allylmagnesium Bromide
Mp 63–65 °C.

IR (film): ν = 3230 (OH), 3070 (CH), 3035 (CH), 2955 (CH), 1605 cm^{-1} (Ph).

^{1}H NMR ($CDCl_3$): δ = 0.92 (3 H, t, *J* = 8.0 Hz, CH_3), 1.22–1.51 (5 H, m, C*H*CH_2CH_2Me), 1.60–1.71 (1 H, m, C*H*CH_2CH_2Me), 2.16–2.26 (1 H, m, C*H*CH=C), 2.45–2.55 (1 H, m, C*H*CH=C), 2.63–2.71 (1 H, m, C*H*Bu), 3.78 (2 H, s, CH_2Ph), 5.04 (1 H, d, *J* = 10.0 Hz, CH=C), 5.08 (1 H, d, *J* = 17.0 Hz, CH=C), 5.58 (1 H, br s, OH), 5.85 (1 H, dddd, *J* = 17.0, 10.0, 7.5, 6.5 Hz, CH=C), 7.20–7.40 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 14.08, 22.91, 28.93, 29.55, 34.23, 59.16, 65.61, 115.95, 127.14, 128.24, 129.53, 136.98, 138.51.

HRMS: *m/z* Found M^+, 233.1772. $C_{15}H_{23}NO$ requires M, 233.1780.

MS: *m/z* (%) = 233 (0.1, M^+), 192 (38, M – C_3H_5), 91 (100, CH_2Ph).

Hydroxylamine from 8 and Allylmagnesium Bromide
Oil.

IR (film): ν = 3470 (OH), 3070 (CH), 3030 (CH), 2935 (CH), 1605 cm^{-1} (Ph).

^{1}H NMR ($CDCl_3$): δ = 1.35–1.86 [10 H, m, (CH_2)$_5$], 2.44 (2 H, d, *J* = 7.5 Hz, CH_2CH=C), 3.89 (2 H, s, CH_2Ph), 4.25 (1 H, br s, OH), 5.07 (1 H, d, *J* = 10.0 Hz, CH=C), 5.09 (1 H, d, *J* = 17.0 Hz, CH=C), 5.99 (1 H, ddt, *J* = 17.0, 10.0, 7.5 Hz, CH=C), 7.20–7.45 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 21.78, 26.25, 32.38, 37.46, 54.76, 62.44, 116.67, 126.81, 128.25, 128.96, 135.75, 140.13.

HRMS: *m/z* Found M^+, 245.1780. $C_{16}H_{23}NO$ requires M, 245.1780.

MS: *m/z* (%) = 245 (0.1, M^+), 204 (38, M – C_3H_5), 91 (100, CH_2Ph).

Stannanes 11; General Procedure
To the appropriate homoallylic amine **7** (2.5 mmol) in anhyd MeCN (10 mL) was added K_2CO_3 (0.5 g, 3.7 mmol) and (tributylstannyl)methyl methanesulfonate (**10**;[9] 1.99 g, 5.0 mmol) under N_2 at r.t. The mixture was warmed to 55–60 °C for 2 d and was cooled to r.t. and aq $NaHCO_3$ (20 mL) was added. The mixture was extracted into EtOAc (3 × 20 mL), dried ($MgSO_4$), evaporated and purified by column chromatography [basic alumina, light petroleum–EtOAc (99:1)] to give the corresponding stannanes **11**.

11a
Oil.

IR (film): ν = 3065 (CH), 3030 (CH), 2925 (CH), 1605 cm^{-1} (Ph).

^{1}H NMR ($CDCl_3$): δ = 0.82–1.01 [18 H, m, NCHCH_3 and Sn(CH_2CH_2CH_2CH_3)$_3$], 1.14–1.51 [12 H, m, Sn(CH$_2$CH_2CH_2CH$_3$)$_3$], 1.98–2.07 (1 H, m, C*H*CH=C), 2.34–2.54 (3 H, m, C*H*CH=C and NCH_2Sn), 2.65–2.75 (1 H, m, C*H*Me), 3.51 (2 H, ABq, *J* = 13.5 Hz, CH_2Ph), 4.98 (1 H, d, *J* = 10.0 Hz, CH=C), 5.01 (1 H, d, *J* = 17.0 Hz, CH=C), 5.75–5.87 (1 H, m, CH=C), 7.18–7.40 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 9.50, 13.54, 13.60, 27.43, 37.25, 38.00, 42.07, 57.19, 57.24, 115.43, 126.49, 128.04, 128.54, 137.43, 140.90.

HRMS: *m/z* Found M^+, 479.2577. $C_{25}H_{45}N^{120}Sn$ requires M, 479.2574.

MS: *m/z* (%) = 479 (0.6, M^+), 188 (100, M – $SnBu_3$), 91 (86, CH_2Ph).

11b
Oil.

IR (film): ν = 3065 (CH), 3030 (CH), 2930 (CH), 1605 cm^{-1} (Ph).

^{1}H NMR ($CDCl_3$): δ = 0.78–0.94 [18 H, m, CH(CH_2)$_3$CH_3 and Sn(CH_2CH$_2$CH$_2$CH_3)$_3$], 1.17–1.57 [18 H, m, Sn(CH$_2$CH_2CH$_2$CH$_2$CH$_3$)$_3$ and CH(CH_2)$_3$CH$_3$], 1.94–2.05 (1 H, m, C*H*CH=C), 2.33–2.57 (4 H, m, C*H*CH=C, NC*H*Bu and NCH$_2$Sn), 3.57 (2 H, ABq, *J* = 13.5 Hz, CH_2Ph), 4.94–5.05 (2 H, m, CH$_2$=C), 5.72–5.84 (1 H, m, CH=C), 7.15–7.35 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 9.49, 13.66, 14.11, 22.98, 27.45, 28.94, 29.32, 29.90, 33.43, 36.82, 57.63, 61.47, 115.39, 126.52, 128.40, 128.75, 137.90, 140.72.

HRMS: *m/z* Found M$^+$, 521.3045. $C_{28}H_{51}N^{119}Sn$ requires M, 521.3044.

MS: *m/z* (%) = 521 (0.1, M$^+$), 230 (100, M – $SnBu_3$), 91 (72, CH_2Ph).

11c
Oil.

IR (film): ν = 3065 (CH), 2925 (CH), 1605 cm^{-1} (Ph).

^{1}H NMR ($CDCl_3$): δ = 0.75–1.06 [21 H, m, CH(CH_3)$_2$ and Sn(CH_2CH$_2$CH$_2$CH_3)$_3$], 1.22–1.60 [12 H, m, Sn(CH$_2$CH_2CH$_2$CH$_2$CH$_3$)$_3$], 1.79–1.93 (1 H, m, C*H*Me$_2$), 2.10–2.21 (1 H, m, C*H*CH=C), 2.21–2.30 (1 H, m, NC*H*Pr), 2.34–2.51 (1 H, m, C*H*CH=C), 2.53 (2 H, ABq, *J* = 12.5 Hz, NCH$_2$Sn), 3.60 (2 H, ABq, *J* = 13.5 Hz, CH_2Ph), 4.96 (1 H, d, *J* = 10.0 Hz, CH=C), 5.03 (1 H, d, *J* = 17.0 Hz, CH=C), 5.82–5.93 (1 H, m, CH=C), 7.17–7.36 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 9.53, 13.66, 20.59, 21.37, 27.46, 30.72, 31.09, 37.83, 58.67, 66.95, 114.95, 126.53, 128.62, 128.92, 139.24, 140.57.

HRMS: *m/z* Found M$^+$, 507.2873. $C_{27}H_{49}N^{120}Sn$ requires M, 507.2887.

MS: *m/z* (%) = 507 (0.2, M$^+$), 216 (100, M – $SnBu_3$), 91 (97, CH_2Ph).

Cyclization of the Stannanes 11; General Procedure
To the appropriate stannane **11** (0.4 mmol) in anhyd hexane–Et_2O (2 mL, 10:1) at –78 °C under N_2 was added BuLi (0.33 mL, 0.8 mmol, 2.5 M in hexanes). The mixture was allowed to warm to r.t. and stirred for 5 h. The mixture was cooled to –78 °C, quenched with MeOH (2 mL) and was allowed to warm to r.t. The mixture was evaporated and purified by column chromatography [silica gel, light petroleum–EtOAc (49:1 to 4:1)] to give the corresponding pyrrolidines **12** as a mixture of diastereomers (approx. 6:1).

***cis*-12a**
Oil.

IR (film): ν = 3065 (CH), 2970 (CH), 2875 (CH), 2785 (CH), 1600 cm^{-1} (Ph).

^{1}H NMR (C_6D_6): δ = 1.03 (3 H, d, *J* = 6.5 Hz, NCH$_2$CHCH_3), 1.08–1.16 [1 H, m, NCH(Me)C*H*], 1.18 (3 H, d, *J* = 6.5 Hz, NCHCH_3), 1.93–2.09 [2 H, m, NCH(Me)C*H*C*H*], 2.30 (1 H, dd, *J* = 9.5, 8.0 Hz, NC*H*^{A}H^{B}CH), 2.39–2.47 (1 H, m, NC*H*Me), 2.68 (1 H, dd, *J* = 9.5, 3.5 Hz, NCH^A*H*^{B}CH), 3.57 (2 H, ABq, *J* = 13.0 Hz, CH_2Ph), 7.17–7.35 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 19.20, 21.69, 29.78, 42.75, 58.00, 60.35, 61.23, 126.61, 128.08, 128.81, 139.99.

HRMS: *m/z* Found M$^+$, 189.1523. $C_{13}H_{19}N$ requires M, 189.1517.

MS: *m/z* (%) = 189 (9, M$^+$), 91 (100, CH_2Ph).

***cis*-12b**
Oil.

IR (film): ν = 3065 (CH), 3030 (CH), 2930 (CH), 1605 cm^{-1} (Ph).

^{1}H NMR (C_6D_6): δ = 0.97–1.04 [3 H, m, (CH$_2$)$_3$CH_3], 1.05 (3 H, d, *J* = 6.5 Hz, NCH$_2$CHCH_3), 1.15 [1 H, ddd, *J* = 12.0, 9.0, 6.5 Hz, NCH(Bu)C*H*], 1.28–1.51 (5 H, m, NCHC*H*CH$_2$CH_2Me), 1.70–1.81 (1 H, m, NCHC*H*CH$_2$CH$_2$Me), 1.96–2.05 (1 H, m, NCH$_2$C*H*Me), 2.05–2.13 [1 H, m, NCH(Bu)C*H*], 2.30 (1 H, dd, *J* = 9.5, 8.0 Hz, NC*H*^{A}H^{B}CH), 2.35–2.44 (1 H, m, NC*H*Bu), 2.69 (1 H, dd, *J* = 9.5, 3.5 Hz, NCH^A*H*^{B}CH), 3.61 (2 H, ABq, *J* = 13.0 Hz, CH_2Ph), 7.16–7.35 (5 H, m, C_6H_5).

NOE enhancement at δ = 2.39 on irradiating at δ = 2.01 and at 2.08; enhancement at δ = 2.01 and at 2.08 on irradiating at δ = 2.39.

^{13}C NMR (C_6D_6): δ = 14.16, 21.69, 23.32, 28.55, 29.96, 34.04, 40.27, 58.54, 61.53, 65.40, 126.66, 128.58, 128.76, 140.86.

HRMS: *m/z* Found M$^+$, 231.1994. $C_{16}H_{25}N$ requires M, 231.1987.

MS: *m/z* (%) = 231 (2, M$^+$), 174 (100, M – C_4H_9), 91 (84, CH_2Ph).

***cis*-12c**
Oil.

IR (film): ν = 3030 (CH), 2930 (CH), 1605 cm^{-1} (Ph).

^{1}H NMR (C_6D_6): δ = 0.97 (3 H, d, *J* = 7.0 Hz, NCH$_2$CHCH_3), 1.01 (3 H, d, *J* = 7.0 Hz, NCHCHCH_3), 1.08 (3 H, d, *J* = 7.0 Hz, NCHCHCH_3), 1.17 [1 H, ddd, *J* = 12.5, 9.5, 6.5 Hz, NCH(Pr)C*H*], 1.79 [1 H, dt, *J* = 12.5, 7.5 Hz, NCH(Pr)C*H*], 1.87–2.04 (2 H, m, NCH$_2$C*H* and C*H*Me$_2$), 2.30 (1 H, dd, *J* = 9.5, 7.5 Hz, NC*H*^{A}H^{B}CH), 2.38 (1 H, ddd, *J* = 9.5, 7.5, 4.5 Hz, NC*H*Pr), 2.65 (1 H, dd, *J* = 9.5, 4.0 Hz, NCH^A*H*^{B}CH), 3.54 (2 H, ABq, *J* = 13.0 Hz, CH_2Ph), 7.17–7.34 (5 H, m, C_6H_5).

^{13}C NMR (C_6D_6): δ = 15.34, 20.22, 21.03, 28.38, 29.67, 33.81, 58.75, 61.67, 70.21, 126.62, 128.21, 128.45, 140.95.

HRMS: *m/z* Found M$^+$, 217.1835. $C_{15}H_{23}N$ requires M, 217.1835.

MS: *m/z* (%) = 218 (0.5, MH$^+$), 174 (99, M – C_3H_7), 91 (100, CH_2Ph).

Stannane 14
N,*N*-Diisopropylethylamine (0.8 mL, 4.7 mmol) and **10**[9] (1.9 g, 4.7 mmol) were added to 2-allylpyrrolidine[18] (473 mg, 4.3 mmol, prepared from the pyrrolidine **13**[17] and CF_3CO_2H in CH_2Cl_2) in MeCN (10 mL) under N_2 at r.t. After 12 h, aq NaCl solution (40 mL) was added and the mixture was extracted into CH_2Cl_2 (2 × 20 mL), dried ($MgSO_4$), evaporated and purified by column chromatography [basic alumina, light petroleum–EtOAc (9:1)] to give the stannane **14** as an oil.

IR (film): ν = 2925 (CH), 2870 (CH), 2855 (CH), 1640 cm^{-1} (C=C).

^{1}H NMR (C_6D_6): δ = 0.89–1.00 [15 H, m, Sn(CH_2CH$_2$CH$_2$CH_3)$_3$], 1.30–1.62 [13 H, m, NCH$_2$C*H* and Sn(CH$_2$CH_2CH$_2$CH$_3$)$_3$], 1.70–1.80 (2 H, m, NCH$_2$C*HCH*), 1.90–2.00 (1 H, m, NCH$_2$CH$_2$C*H*), 2.00–2.21 (2 H, m, CH$_2$C=C), 2.15 (1 H, dt, *J* = 9.0, 8.5 Hz, NCH), 2.43–2.51 (1 H, m, NCH), 2.53 (1 H, d, *J* = 13.0 Hz, NCHSn), 2.89 (1 H, d, *J* = 13.0 Hz, NCHSn), 3.01 (1 H, tt, *J* = 7.0, 6.5 Hz, NCH), 5.02 (1 H, dd, *J* = 10.0, 2.5 Hz, CH=C), 5.08 (1 H, dd, *J* = 17.0, 2.5 Hz, CH=C), 5.77 (1 H, ddt, *J* = 17.0, 10.0, 7.0 Hz, CH=C).

^{13}C NMR (C_6D_6): δ = 9.89, 12.66, 21.01, 27.11, 29.02, 29.95, 37.65, 39.58, 57.71, 67.50, 115.62, 135.43.

HRMS: *m/z* Found M$^+$, 415.2275. $C_{20}H_{41}N^{120}Sn$ requires M, 415.2261.

MS: *m/z* (%) = 415 (2.3, M$^+$), 124 (100, M – $SnBu_3$), 55 (20, C_4H_7).

Cyclization of the Stannane 14
The cyclization of the stannane **14** was carried out in the same way as the stannanes **11**, and after quenching with the electrophile (3 molar equiv), an excess of a solution of picric acid in EtOH was added. The mixture was evaporated and purified by column chromatography [silica gel, CH_2Cl_2–MeOH (95:5)] to give the picrate

salt of the pyrrolizidines **15** and **16** as a mixture of diastereomers (approx. 3:1).

Picrate Salt of the Pyrrolizidine 15 + 16 (E = H)
(Lit.[27] 1:1 mixture of free base)

Needles; mp 160–162 °C.

IR (film): ν = 2960 (CH), 2880 (CH), 1495 (NO), 1360 cm^{-1} (NO).

^1H NMR ($CDCl_3$): δ (major diastereomer) = 1.15 (3 H, d, *J* = 6.5 Hz, CH_3),1.24–1.36 (1 H, m, NCH_2CH_2CH), 1.84–1.91 (1 H, m, $CHCH_3$), 1.92–2.00 (1 H, m, NCH_2CH_2CH), 2.09–2.19 (1 H, m, $NCH_2CH^AH^B$), 2.20–2.32 (2 H, m, $NCH_2CH^AH^B$ and NCHCH-CHMe), 2.33–2.49 (1 H, m, NCHCHCHMe), 2.50–2.65 (1 H, m, $NCH^AH^BCH_2$), 3.09–3.10 (1 H, m, NCHCHMe), 3.63–3.66 (1 H, m, $NCH^AH^BCH_2$), 4.00–4.02 (1 H, m, NCHCHMe), 4.42–4.45 (1 H, m, $NCHCH_2CHMe$), 8.85 (2 H, s, C_6H_2 of picrate).

^{13}C NMR ($CDCl_3$): δ (major diastereomer) = 15.74, 24.71, 30.55, 35.23, 40.00, 55.05, 62.00, 68.62, 126.58, 128.08, 141.71, 162.39.

HRMS: *m/z* Found M^+ – picric acid, 125.1205. $C_8H_{15}N$ requires M, 125.1206.

MS: *m/z* (%) = 229 (71, picric acid), 125 (91, M^+ – picric acid), 110 (22, $C_7H_{12}N$), 83 (100, C_5H_9N).

Picrate Salt of the Pyrrolizidine (15 + 16) (E = $SiMe_3$)
Waxy solid.

IR (film): ν = 2960 (CH), 1495 (NO), 1365 cm^{-1} (NO).

^1H NMR ($CDCl_3$): δ (major diastereomer) = 0.06 [9 H, s, $(CH_3)_3Si$], 0.70 (1 H, dd, *J* = 16, 8 Hz, CHSi), 0.76 (1 H, dd, *J* = 16, 5 Hz, CHSi),1.25–1.30 (1 H, m, NCHCHCHCH$_2$Si), 1.80–1.92 (1 H, m, NCH_2CH_2CH), 2.14–2.27 (2 H, m, NCH_2CH_2), 2.27–2.34 (2 H, m, NCH_2CH_2CH and NCHCHCH$_2$Si), 2.36–2.49 (1 H, m, NCHCHCHCH$_2$Si), 2.52–2.65 (1 H, m, CHCH$_2$Si), 3.07–3.10 (1 H, m, $NCH^AH^BCH_2$), 3.63–3.65 (1 H, m, $NCH^AH^BCH_2$), 3.97–4.00 (1 H, m, NCHCHCH$_2$Si), 4.40–4.42 (1 H, m, NCHCH$_2$CHCH$_2$Si), 8.94 (2 H, s, C_6H_2 of picrate).

^{13}C NMR ($CDCl_3$): δ (major diastereomer) = –1.11, 19.24, 24.64, 30.59, 36.98, 40.96, 55.00, 62.99, 68.30, 126.48, 130.51, 140.71, 160.21.

HRMS: *m/z* Found MH^+ – picrate, 198.1680.$C_{11}H_{24}NSi$ requires M, 198.1678.

MS: *m/z* (%) = 228 (100, picrate), 198 (100, M^+ – picrate).

Picrate Salt of the Pyrrolizidine 15 + 16 (E = $SnBu_3$)
Oil.

IR (film): ν = 2965 (CH), 1495 (NO), 1365 cm^{-1} (NO).

^1H NMR ($CDCl_3$): δ (major diastereomer) = 0.84–0.92 [17 H, m, $Sn(CH_2CH_2CH_2CH_3)_3$ and $CHCH_2Sn$], 1.26–1.32 [7 H, m, NCHCHCHCH$_2$Sn and $Sn(CH_2CH_2CH_2)_3$], 1.43–1.57 [6 H, m, $Sn(CH_2CH_2CH_2)_3$], 1.80–1.90 (1 H, m, NCH_2CH_2CH), 2.05–2.45 (5 H, m, NCHCHCHCH$_2$Sn, NCH_2CH_2CH and NCHCHCH$_2$Sn), 2.60–2.75 (1 H, m, CHCH$_2$Sn), 3.07–3.10 (1 H, m, $NCH^AH^BCH_2$), 3.63–3.66 (1 H, m, $NCH^AH^BCH_2$), 3.90–4.00 (1 H, m, NCHCHCH$_2$Sn) 4.42–4.46 (1 H, m, NCHCH$_2$CHCH$_2$Sn), 8.90 (2 H, s, C_6H_2 of picrate).

^{13}C NMR ($CDCl_3$): δ (major diastereomer) = 9.37, 10.25, 13.57, 24.71, 27.29, 29.09, 30.66, 39.42, 41.85, 55.07, 63.59, 68.44, 126.53, 128.22, 141.76, 162.30.

HRMS: *m/z* Found MH^+ – picrate, 416.2339. $C_{20}H_{42}N^{120}Sn$ requires M, 416.2339.

MS: *m/z* (%) = 416 (100, MH^+ – picrate), 228 (100, picrate).

Anal. Calcd for $C_{26}H_{44}N_4O_7Sn$: C, 48.54; H, 6.89; N, 8.71. Found C, 48.98; H, 6.99; N, 8.30.

Picrate Salt of the Pyrrolizidine 15 + 16 (E = $CH_2CH{=}CH_2$)
Waxy solid.

IR (film): ν = 2965 (CH), 1640 (C=C), 1495 (NO), 1365 cm^{-1} (NO).

^1H NMR ($CDCl_3$): δ (major diastereomer) = 1.25–1.32 (1 H, m, NCHCHCHCH$_2$CH$_2$), 1.56–1.61 (2 H, m, CH$_2$CH$_2$C=C), 1.80–1.95 (1 H, m, NCH_2CH_2CH), 2.09–2.27 (5 H, m, NCH_2CH_2CH and CH$_2$C=C), 2.30–2.60 [3 H, m, NCHCH(CH$_2$CH$_2$C=C)CH], 3.07–3.12 (1 H, m, $NCH^AH^BCH_2$), 3.60–3.70 (1 H, m, $NCH^AH^BCH_2$), 4.03–4.10 (1 H, m, NCHCHCH$_2$CH$_2$C=C), 4.42–4.46 (1 H, m, NCHCH$_2$CHCH$_2$), 4.98–5.06 (2 H, m, C=CH$_2$), 5.73–5.80 (1 H, m, CH=C), 8.86 (2 H, s, C_6H_2 of picrate).

^{13}C NMR ($CDCl_3$): δ (major diastereomer) = 24.67, 30.60, 31.00, 32.06, 38.18, 40.15, 55.08, 60.76, 68.24, 115.75, 126.57, 128.17, 137.04, 141.73, 162.27.

HRMS: *m/z* Found MH^+ – picrate, 166.1593. $C_{11}H_{20}N$ requires M, 166.1596.

MS: *m/z* (%) = 228 (100, picrate), 166 (100, MH^+ – picrate).

Picrate Salt of the Pyrrolizidine 15 + 16 [E = C(OH)Ph2]
Foam.

IR (film): ν = 3425 (OH), 1605 (Ph), 1495 (NO), 1365 cm^{-1} (NO).

^1H NMR ($CDCl_3$): δ (major diastereomer) = 1.26–1.38 (1 H, m, NCHCHCHCH$_2$COH), 1.75–1.90 (1 H, m, NCH_2CH_2CH), 2.15–2.20 (2 H, m, $NCH_2CH_2CH_2$), 2.25–2.53 [6 H, m, NCH_2CH_2CH and NCHCH(CH$_2$COH)CH], 3.08–3.15 (1 H, m, $NCH^AH^BCH_2$), 3.50–3.61 (1 H, m, $NCH^AH^BCH_2$), 3.95–4.05 (1 H, m, NCHCHCH$_2$COH), 4.15–4.30 (1 H, m, NCHCH$_2$CHCH$_2$), 7.17–7.42 (10 H, m, 2 × C_6H_5), 8.84 (2 H, s, C_6H_2 of picrate).

^{13}C NMR ($CDCl_3$): δ (major diastereomer) = 24.41, 30.48, 36.38, 39.14, 44.14, 55.00, 61.18, 66.88, 77.72, 125.84, 126.60, 128.14, 128.42, 141.62, 145.54, 146.72, 162.24.

HRMS: *m/z* Found MH^+ – picrate, 308.2017. $C_{21}H_{26}NO$ requires M, 308.2014.

MS: *m/z* (%) = 308 (100, MH^+ – picric acid), 228 (100, picrate), 124 (26, $C_8H_{14}N$).

Stannane 18
In the same way as the stannanes **11** or **14**, (*R*)- or (*S*)-*N*-α-methylbenzylbut-3-enylamine[28] gave the stannane (*R*)- or (*S*)-**18** (48–59%) as an oil.

(*R*)-18
$[\alpha]_D^{23}$ +36.2 (*c* = 1.0, $CHCl_3$).

IR (film): ν = 3065 (CH), 3025 (CH), 2925 (CH), 1600 cm^{-1} (Ph).

^1H NMR ($CDCl_3$): δ = 0.81–1.01 [18 H, m, $NCHCH_3$ and $Sn(CH_2CH_2CH_2CH_3)_3$], 1.23–1.59 [12 H, m, $Sn(CH_2CH_2CH_2CH_3)_3$], 2.18–2.37 (3 H, m, $NCHCH_2$), 2.45–2.54 (1 H, m, NCH), 2.68 (2 H, ABq, *J* = 12.0 Hz, NCH_2Sn), 3.52 (1 H, q, *J* = 7.0 Hz, NCHMe), 4.98 (1 H, d, *J* = 10.0 Hz, CH=C), 5.02 (1 H, d, *J* = 17.0 Hz, CH=C), 5.76 (1 H, dddd, *J* = 17.0, 10.0, 7.5, 6.5 Hz, CH=C), 7.18–7.39 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 10.19, 13.67, 18.38, 27.46, 29.26, 32.13, 39.19, 54.00, 63.37, 115.22, 126.54, 127.55, 128.04, 136.98, 145.28.

HRMS: *m/z* Found M^+, 479.2588. $C_{25}H_{45}N^{120}Sn$ requires M, 479.2574.

MS: *m/z* (%) = 479 (0.2, M^+), 188 (92, M – $SnBu_3$), 105 (100, PhCHMe).

Cyclization of the Stannane 18
The stannane **18** was subjected to the same cyclization conditions as that described for the stannane **11**. Alternatively, cyclization was ef-

fected using the solvent THF or THF with (–)-sparteine (2 molar equiv) at –78 °C to give the pyrrolidines **19** and **20** as a mixture of diastereomers (approx. 1:1 to 4:1) as an oil.

IR (film): ν = 3025 (CH), 2930 (CH), 1600 cm^{-1}. (Ph)

^1H NMR ($CDCl_3$): δ = 0.98 (3 H, d, *J* = 7.0 Hz, NCH_2CHCH_3), 1.01 (3 H, d, *J* = 7.0 Hz, NCH_2CHCH_3), 1.27–1.37 (2 H, m, NCH_2CHH), 1.38 (6 H, d, *J* = 7.0 Hz, $NCHCH_3$), 1.90 (1 H, dd, *J* = 9.0, 8.0 Hz, NC*H*CHMe), 1.96 (1 H, dd, *J* = 9.0, 7.5 Hz, NC*H*CHMe), 1.92–2.09 (2 H, m, NCH_2CHH), 2.15–2.30 (2 H, m, NCH_2CHMe), 2.36 (1 H, dt, *J* = 9.0, 6.5 Hz, $NCHCH_2$), 2.42–2.52 (2 H, m, NCH_2CH_2), 2.67 (1 H, dd, *J* = 9.0, 7.5 Hz, NC*H*CHMe), 2.87 (1 H, td, *J* = 8.5, 5.5 Hz, $NCHCH_2$), 2.94 (1 H, m, dd, *J* = 9.0, 7.5 Hz, NC*H*CHMe), 3.18 (1 H, q, *J* = 7.0 Hz, NC*H*Me), 3.21 (1 H, q, *J* = 7.0 Hz, NC*H*Me), 7.19–7.38 (10 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 20.50, 20.90, 22.99, 23.19, 31.74, 31.87, 32.52, 32.63, 52.68, 52.94, 61.01, 61.28, 66.02, 66.06, 126.75, 126.80, 127.21, 127.25, 128.23, 128.40, 145.72, 145.75.

HRMS: *m*/*z* Found M^+, 189.1513. $C_{13}H_{19}N$ requires M, 189.1517.

MS: *m*/*z* (%) = 189 (10, M^+), 174 (100, M – Me), 105 [27, CH(Me)Ph].

Stannane 22 (R = H)

In the same way as the stannane **14**, (*R*)-*N*-but-3-enylphenylglycinol[22] gave the stannane (*R*)-**22** (R = H) (60%) as an oil; $[\alpha]_D^{23}$ +31.9 (*c* = 1.4, $CHCl_3$).

IR (film): ν = 3385 (OH), 3005 (CH), 2975 (CH), 2935 (CH), 1645 cm^{-1} (C=C).

^1H NMR ($CDCl_3$): δ = 0.81–0.94 [15 H, m, $Sn(CH_2CH_2CH_2CH_3)_3$], 1.10–1.62 [12 H, m, $Sn(CH_2CH_2CH_2CH_3)_3$], 2.18 (1 H, d, *J* = 12.5 Hz, NCHSn), 2.21–2.34 (3 H, m, $NCH^AH^BCH_2$), 2.51–2.64 (1 H, m, $NCH^AH^BCH_2$), 2.68 (1 H, d, *J* = 12.5 Hz, NCHSn), 3.11 (1 H, br d, *J* = 8.5 Hz, OH), 3.57–3.66 (1 H, m, C*H*OH), 3.81 (1 H, dd, *J* = 10, 5.5 Hz, NC*H*Ph), 3.94 (1 H, t, *J* = 10 Hz, C*H*OH), 5.04 (1 H, d, *J* = 8.0 Hz, CH=C), 5.09 (1 H, d, *J* = 16.0 Hz, CH=C), 5.76 (1 H, ddt, *J* = 16.0, 8.0, 7.0 Hz, CH=C), 7.17–7.40 (5 H, m,C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 9.69, 13.69, 27.45, 29.20, 32.41, 36.93, 53.06, 60.77, 67.09, 116.24, 127.79, 128.13, 129.15, 135.83, 136.36.

HRMS: *m*/*z* Found M^+ + H, 496.2605. $C_{25}H_{46}NO^{120}Sn$ requires M + H, 496.2601.

MS: *m*/*z* (%) = 496 (4, M^+ + H), 204 (100, M – $SnBu_3$).

Stannane 22 (R = Me)

The stannane **22** (R = H) (250 mg, 0.51 mmol) in anhyd THF (2 mL) was added to NaH (31 mg, 0.77 mmol, 60% dispersion in oil) in anhyd THF (2 mL) under N_2 at r.t. After 2 h, MeI (0.048 mL, 0.77 mmol) was added and the mixture was stirred for 16 h. MeOH (0.5 mL) was added, the solvent was evaporated and the residue was purified by column chromatography [silica gel, light petroleum–EtOAc (49:1 to 4:1)] to give the stannane **22** (R = Me) (187 mg, 72%) as an oil; $[\alpha]_D^{23}$ –19.6 (*c* = 0.5, $CHCl_3$).

IR (film): ν = 3065 (CH), 3030 (CH), 2925 (CH), 1595 cm^{-1} (Ph).

^1H NMR ($CDCl_3$): δ = 0.81–0.98 [15 H, m, $Sn(CH_2CH_2CH_2CH_3)_3$], 1.23–1.56 [12 H, m, $Sn(CH_2CH_2CH_2CH_3)_3$], 2.18–2.28 (2 H, m, NCH_2CH_2), 2.32–2.42 (1 H, m, $NCH^AH^BCH_2$), 2.48–2.60 (1 H, m, $NCH^AH^BCH_2$), 2.69 (2 H, ABq, *J* = 12.0 Hz, NCH_2Sn), 3.32 (3 H, s, OCH_3), 3.60–3.76 (3 H, m, $NCHCH_2OMe$), 5.00 (1 H, d, *J* = 10.0 Hz, CH=C), 5.03 (1 H, d, *J* = 17.0 Hz, CH=C), 5.74 (1 H, ddt, *J* = 17.0, 10.0, 7.0 Hz, CH=C), 7.21–7.36 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 10.21, 13.66, 27.47, 29.25, 32.11, 39.70, 54.60, 58.82, 67.64, 74.84, 115.27, 126.97, 128.02, 128.33, 136.87, 141.07.

HRMS: *m*/*z* Found M^+, 509.2693. $C_{26}H_{47}NO^{120}Sn$ requires M, 509.2680.

MS: *m*/*z* (%) = 509 (6, M^+), 218 (100, M – $SnBu_3$),135 [86, $CH(Ph)CH_2OMe$].

Transmetallation of the Stannane 22 (R = H)

BuLi (0.25 mL, 0.63 mmol, 2.5 M in hexanes) was added to the stannane **22** (R = H) (103 mg, 0.21 mmol) in anhyd THF (2.5 mL) at –78 °C. After 6 h, MeOH (0.5 mL) was added and the mixture was allowed to warm to r.t. Evaporation and purification by column chromatography [basic alumina, light petroleum–EtOAc (99:1)] gave the stannane **22** (R = H) (16.5 mg, 18%), the amine **21** (R = H) (6.5 mg, 18%), the amine **23** (15 mg, 39%) and the oxazolidine **24** (8 mg, 20%).

23

Oil; $[\alpha]_D^{23}$ –50.0 (*c* = 0.3, $CHCl_3$).

IR (film): ν = 3375 (OH), 3005 (CH), 2955 cm^{-1} (CH).

^1H NMR ($CDCl_3$): δ = 2.18 (3 H, s, NCH_3), 2.26 (2 H, q, *J* = 7.5 Hz, $CH_2C{=}C$), 2.38 (1 H, dt, *J* = 12.5, 7.5 Hz, NCH^ACH^B), 2.56 (1 H, dt, *J* = 12.5, 7.5 Hz, NCH^ACH^B), 3.63 (1 H, dd, *J* = 9.5, 5.5 Hz, OCH^ACH^B), 3.79 (1 H, dd, *J* = 9.5, 5.5 Hz, NC*H*Ph), 3.98(1 H, t, *J* = 9.5 Hz, OCH^ACH^B), 5.02 (1 H, d, *J* = 9.0 Hz, CH=C), 5.07 (1 H, d, *J* = 15.0 Hz, CH=C), 5.81 (1 H, ddt, *J* = 15.0, 9.0, 7.5 Hz, CH=C), 7.16–7.39 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 32.24, 36.68, 53.06, 60.37, 68.67, 116.18, 127.88, 128.22, 128.91, 135.40, 136.50.

HRMS: *m*/*z* Found M^+ + H, 206.1545. $C_{13}H_{20}NO$ requires M + H, 206.1545.

MS: *m*/*z* (%) = 206 (8, M^+ + H), 174 (74, M – CH_2OH),164 (73, M – C_3H_5), 131 (100, M – CH_2O – C_3H_4), 91 (74, $PhCH_2$).

Oxazolidine 24:

Oil; $[\alpha]_D^{23}$ –128.2 (*c* = 0.4, $CHCl_3$).

IR (film): ν = 2945 (CH), 2890 (CH), 1660 cm^{-1} (C=C).

^1H NMR ($CDCl_3$): δ = 2.22 (2 H, q, *J* = 8.0 Hz, $CH_2C{=}C$), 2.48 (1 H, dt, *J* = 13.5, 8.0 Hz, NCH^ACH^B), 2.75 (1H, dt, *J* = 13.5, 8.0 Hz, NCH^ACH^B), 3.69 (1 H, t, *J* = 8.0 Hz, OCH^ACH^B), 3.77 (1 H, t, *J* = 8.0 Hz, NC*H*Ph), 4.22 (1 H, d, *J* = 3.0, OCHN), 4.26 (1 H, t, *J* = 8.0 Hz, OCH^ACH^B), 4.80 (1 H, d, *J* = 3.0 Hz, OCHN), 4.99 (1 H, d, *J* = 9.0 Hz, CH=C), 5.03 (1 H, d, *J* = 16.5 Hz, CH=C), 5.81 (1 H, ddt, *J* = 16.5, 9.0, 8.0 Hz, CH=C), 7.25–7.46 (5 H, m, C_6H_5).

^{13}C NMR ($CDCl_3$): δ = 33.68, 52.37, 67.92, 73.74, 87.40, 115.84, 127.45, 127.58, 128.56, 136.28, 139.91.

HRMS: *m*/*z* Found M^+ + H, 204.1387. $C_{13}H_{18}NO$ requires M + H, 204.1388.

MS: *m*/*z* (%) = 204 (45, M^+ + H), 162 (100, M – C_3H_5), 103 (91, Ph-CHCH), 91 (86, $PhCH_2$).

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