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Stereoselective Access to Substituted [(*E*)- or (*Z*)-1-(Trifluoromethyl)-allyl]amines

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Hydrometallation reactions, for example, hydroboration and hydroalumination, on [1-(trifluoromethyl)propargyl]amines lead stereoselectively to the corresponding [(*Z*)- and (*E*)-1-(trifluoromethyl)allyl]amines in good yields; (*Z*)- and (*E*)-allylamines with a free amino group can be obtained in good yields and excellent enantioselectivities from the chiral propargylamines.

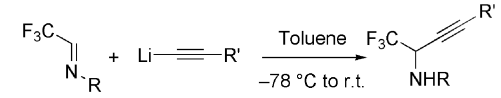
Introduction

Allylamines are highly functionalizable compounds and are thus the focus of numerous studies. The functionalization of the double bond opens the way to a wide range of useful products such as α- and β-amino acids, various alkaloids and carbohydrate derivatives.[1] Many methods have been developed for their asymmetric preparation. Surprisingly, despite the fact that the introduction of fluorine can bring about profound changes in bioactive molecules, only a few methods for the preparation of trifluoromethylated allylamines have been reported. [1-(Trifluoromethyl)-allyl]amines can be obtained in different ways: by trifluoromethylation of unsaturated nitrones,[2] *N*-sulfinimines or *N*-tosylaldimines,[3] or by olefination of fluorinated β-amino sulfones[4] or fluorinated enamine phosphonates.[5] More recently we have shown that the addition of a vinyl Grignard reagent to CF_3-*N*-aryl- and -*N*-alkylaldimines was efficient and did not require an activating *N*-substituent.[6] Similar approaches involving the addition of a vinyl Grignard reagent to activated CF_3-sulfinimine[7] and vinyl trifluoroborate to (trifluoromethyl)iminium species[8] have also been reported. Although different routes to fluorinated allylamines have been reported, a simple and selective access to substituted allylamines is not known. This paper focuses on the partial and stereocontrolled reduction of propargylamines to CF_3-substituted (*Z*)- or (*E*)-allylamines.

Results and Discussion

[1-(Trifluoromethyl)propargyl]amines have previously been synthesized by our group. They were easily prepared by the addition of lithium acetylides in toluene to non-activated CF_3-substituted aldimines **1**–**3** (Table 1).[9]

Table 1. Preparation of propargylamines.



R = Bn **1** → **4**
PMP **2** → **5**
(*R*)-PhCHCH$_2$OMe **3** → **6** (*de* >98%)

Entry	Imine	R′	Product	Yield
1	**1**	$SiMe_3$	**4a**	83%
2	**1**	Bu	**4b**	94%
3	**1**	Ph	**4c**	87%
4	**2**	$SiMe_3$	**5a**	84%
5	**2**	Bu	**5b**	71%
6	**2**	Ph	**5c**	78%
7	**3**	$SiMe_3$	**6a**	95%
8	**3**	Bu	**6b**	77%
9	**3**	Ph	**6c**	90%

The propargylamines were obtained in good to excellent yields. From the imine **3**, with the methyl ether of (*R*)-phenylglycinol as a chiral *N*-substituent, [1-(trifluoromethyl)-propargyl]amines **6** were obtained in good yields and with excellent diastereoselectivities (*de* > 98%). In all cases, only one diastereoisomer was detected in the ^1H and ^{19}F NMR spectra of the crude product. The isomer is assumed to have (*R*) configuration by comparison with the results of our previous vinylation reactions.[6]

With [1-(trifluoromethyl)propargyl]amines **4**–**6** in hand, the partial reduction of the triple bond to give (*Z*)-allylamines was first investigated. Under classical conditions using the Lindlar reagent, a mixture of compounds was obtained. Faced with this failure, hydrometallation of the triple bond was investigated, particularly hydroboration.

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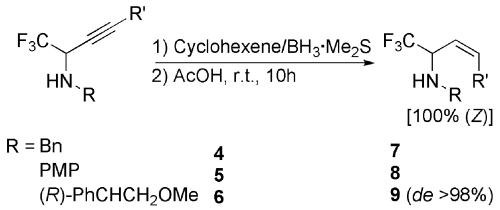
The reaction of propargylamines **4** with the active BH_3 reagent led to the degradation of the starting material. Consequently, the hydroboration reaction was investigated with less reactive borane reagents such as dicyclohexylborane (Table 2).

Table 2. Hydroboration of propargylamines **4**–**6**.



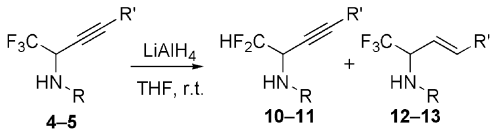
Entry	Imine	R′	Product	Yield
1	**4a**	$SiMe_3$	**7a**	92%
2	**4b**	Bu	**7b**	93%
3	**5a**	$SiMe_3$	**8a**	35%
4	**5c**	Ph	**8c**	32%
5	**6b**	Bu	**9b**	86%
6	**6c**	Ph	**9c**	85%

Under these conditions propargylamines **4a** and **4b** were quantitatively reduced to the corresponding allylamines **7a** and **7b** with excellent stereoselectivity [100% (*Z*)]. However, with propargylamines **5**, the yields were lower (only 32–35%). Interestingly, hydroboration of the chiral CF_3-substituted propargylamines **6b** and **6c** provided the corresponding allylamines **9b** and **9c** in excellent yields without loss of stereoselectivity (*de* >98%). It is worth noting that in all cases (Entries 1–6) excellent stereoselectivity of the reduction reaction was obtained [signals of the (*E*) isomer were not observed in the NMR spectra].

In the same way, in order to obtain the corresponding [(*E*)-1-(trifluoromethyl)allyl]amines, partial and selective reduction was attempted by hydrometallation with, in this case, hydroalumination reagents. The use of DIBAL-H at room temperature or at reflux in THF led to the recovery of the starting amines **4** and **5**. Use of the more reactive Red-Al® afforded a complex mixture of compounds when the reaction was performed at 0 °C. ^1H and ^{19}F NMR analyses of this mixture highlighted the presence of triple and double bonds as well as the presence of CF_2H, CFH_2 and CH_3 groups.

Faced with these disappointing results, we investigated the reduction of the triple bond with $LiAlH_4$ (LAH). Only a few examples of the reduction of non-fluorinated propargylamines to the corresponding (*E*)-allylamines have been described,[10] and there is no precedent for the reduction of a fluorinated propargylamine. The first attempts were realized on amines **4a** and **5a** with 4 equiv. of LAH at low temperature in THF, but only the starting materials were recovered. However, at room temperature, either [1-(trifluoromethyl)allyl]amine or [1-(difluoromethyl)propargyl]amine were obtained depending on the starting propargylamine. The results are presented in Table 3.

Table 3. Reduction of propargylamines with LAH at room temperature.



Entry	Amine	Time	CF_2H amine,[a] yield	Allylamine,[a] yield
1	**4a**	11 h	**10a**, –	**12a**, 100%
2	**4b**	13 h	**10b**, –	**12b**, 100%
3	**4c**	12 h	**10c**, –	**12c**, 100%
4	**5a**	1 h	**11a**, >90%	**13a**, –
5	**5b**	10 h	**11b**, –	**13b**, 100%
6	**5c**	3 h	**11c**, 36%	**13c**, 64%

[a] NMR signal ratio of the crude product.

The *N*-benzylpropargylamines **4** were exclusively converted into [1-(trifluoromethyl)allyl]amines **12** in good yields and with excellent stereoselectivity [(*E*)/(*Z*) = 100:0]. Surprisingly, the reactivity of the *N*-(*p*-methoxyphenyl)propargylamines **5** depended on the nature of the R′ group. With the butyl group, only the allylamine **13b** was obtained. With the phenyl group, a 36:64 mixture of [1-(difluoromethyl)propargyl]amine **11c** and [1-(trifluoromethyl)allyl]-amine **13c** was formed, whereas with a TMS group (Entry 4) only the [1-(difluoromethyl)propargyl]amine was obtained. The formation of the CF_2H amines can be compared with the results obtained with Red-Al®. This latter reaction takes place presumably by deprotonation at C1 and successive elimination of a fluoride ion (Figure 1).

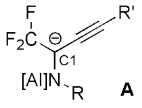
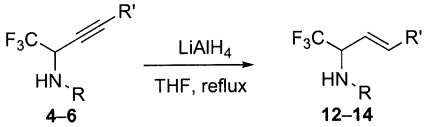


Figure 1. Intermediate **A**.

At a higher temperature the reaction would be expected to favour one pathway more than the other. The reaction was therefore investigated at reflux in order to gain an understanding of the reduction mechanism. The results are reported in Table 4.

Table 4. Reduction of propargylamines with LAH at reflux in THF.

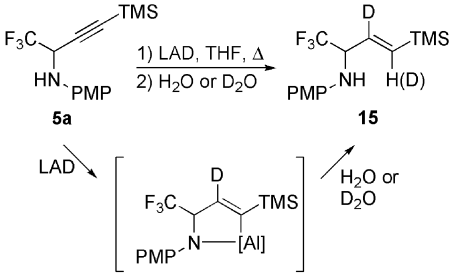


Entry	Amine	R′	Time	Product	Yield
1	**4b**	Bu	1 h	**12b**	94%
2	**4c**	Ph	1.5 h	**12c**	90%
3	**5a**	$SiMe_3$	1 h	**13a**	88%
4	**5b**	Bu	1.5 h	**13b**	89%
5	**5c**	Ph	1 h	**13c**	90%
6	**6a**	$SiMe_3$	1.5 h	**14a**	88%
7	**6c**	Ph	2 h	**14c**	90%

Under these conditions, the reaction was not only faster but also completely chemo- and stereoselective and gave a good yield irrespective of the nature of the substituents on the triple bond and the nitrogen atom. [1-(Trifluoromethyl)-propargyl]amines **4**–**6** were selectively reduced to [(*E*)-1(-trifluoromethyl)allyl]amines **12**–**14** in excellent yields. Under these conditions the reaction of **5a** with LAH (Entry 3) led to a considerable reduction of the proportion of [1-(difluoromethyl)propargyl]amine **11a** (8 vs. >90% at room temperature). CF_2 compounds were not observed in any other case.

Interestingly, hydroalumination of the chiral CF_3-substituted propargylamines **3a** and **3c** provided the corresponding allylamines **14a** and **14c** without any stereochemical loss [*de* >98 and 100% (*Z*), respectively] in excellent yields.

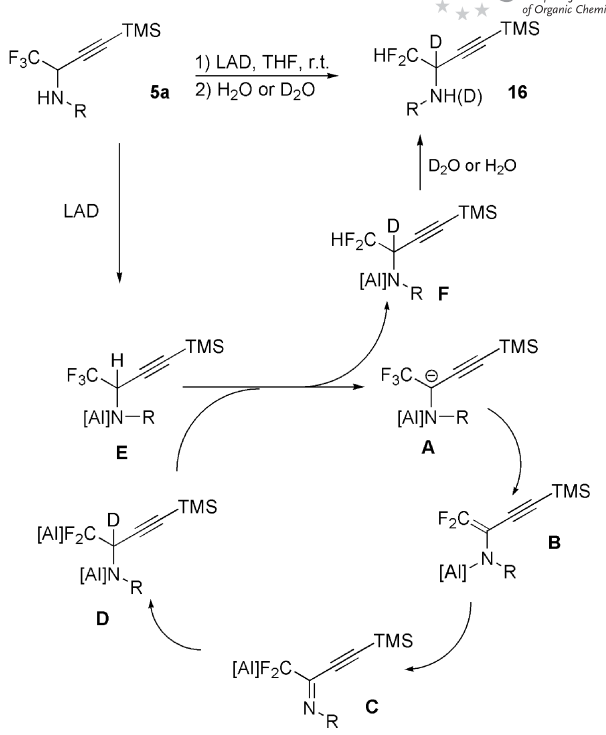
Despite these excellent results obtained at high temperature, we decided to investigate in more detail the course of the two reductive pathways. Such a difference in reactivity induced by temperature, reflected in the reaction times (Entry 4 vs. Entry 5 in Table 3), highlights the fact that **11** and **13** are obtained by two different reaction pathways. To gain a better understanding of the reaction mechanisms, the reactions were carried out with isotopic labelling. Amine **5a** was treated with $LiAlD_4$ (LAD) at room temperature and at reflux in THF, and the mixtures were hydrolysed with either H_2O or D_2O. The results obtained at reflux in THF (Scheme 1) are in accordance with the classical mechanism described in the literature.[11]



Scheme 1. Reaction of **5a** with LAD at reflux.

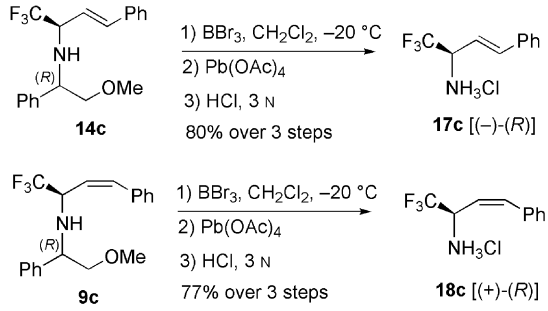
When the reaction was conducted at room temperature, **5a** was converted into compound **16** after hydrolysis with H_2O and D_2O (Scheme 2). First, deuterium was introduced at C1, indicating an addition of D^- to an imine intermediate. Secondly, hydrolysis with water or D_2O produced the same compound **16**, indicating that the last intermediate **F** is an amide (NAl and not CF_2Al but CF_2H). Thus, the mechanism of the reduction can be explained by Scheme 2. Difluoro enamine **B** is expected after deprotonation of **E** at the C1 carbon atom and subsequent loss of a fluoride ion from intermediate **A**; **B** then quickly rearranges to the more stable difluoromethyl imine **C** which is immediately reduced by LAD to afford **D**. This latter deprotonates **E** at C1 to afford **F** and to regenerate **A** which starts the cycle again.

Interestingly, the (*Z*)- or (*E*)-allylamines could be deprotected in order to obtain the free amino group. For example, for compounds **9c** or **14c**, removal of the methyl ether moiety of the (*R*)-phenylglycinol side-chain was very conve-



Scheme 2. Reaction of **5a** with LAD at room temperature.

niently achieved first by demethylation with BBr_3 in CH_2Cl_2[12] and then by the standard $Pb(OAc)_4$[13] method to give the corresponding novel free allylamines in good yields (Scheme 3). The (*R*) configuration of the CF_3-substituted allylamine obtained was assigned by comparison with the optical rotation data reported in the literature: $[\alpha]_D^{25}$ = –50 (*c* = 0.2, MeOH) {ref.[3] $[\alpha]_D^{20}$ = +51.4 [*c* = 1.0, MeOH, for the (*S*) enantiomer]}.



Scheme 3. Synthesis of free [1-(trifluoromethyl)allyl]amines.

Conclusions

This paper describes the stereoselective access to functionalized [(*Z*)- and (*E*)-1-(trifluoromethyl)allyl]amines. These were obtained by partial and selective hydroboration or hydroalumination reduction of [1-(trifluoromethyl)propargyl]amines. In the case of hydroalumination, the competitive formation of allylamine and CF_2H-substituted propargylamine was observed at room temperature. When the reaction was conducted at reflux, only the reduction to (*E*)-allylamines was observed. Isotopic labelling reactions were

also realized in order to gain information on the mechanistic pathways of these reactions. Free [(*Z*)- or (*E*)-1-(trifluoromethyl)allyl]amines were easily obtained with excellent enantioselectivity.

Experimental Section

General Methods: Experiments were carried out under dry argon. All moisture-sensitive reactants were handled under argon. Tetrahydrofuran was distilled from sodium/benzophenone and toluene from calcium hydride. Column chromatography was carried out on Merck SiO_2 (70–230 mesh). NMR spectra were recorded with a Bruker AC 200 spectrometer (^{1}H: 200 MHz; ^{19}F: 188 MHz; ^{13}C: 75 MHz) in $CDCl_3$ solutions. Chemical shifts are reported in ppm relative to Me_4Si and $CFCl_3$ [for ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C)] as internal standards. For the ^{13}C NMR data, reported signal multiplicities were measured relative to C–F coupling. Optical rotations were measured at 589 nm with a Polartronic E-Schmidt-Haensch apparatus. Melting points were determined with a Kofler block melting point apparatus and are uncorrected.

General Procedure for the Alkynylation Reaction: *n*-Butyllithium [1.6 M (hexane), 6 mmol] was added under argon to a cooled (–78 °C) solution of alkyne (6 mmol) in toluene (50 mL). The reaction mixture was stirred for 30 min, and then the (trifluoromethyl)-aldimine (5 mmol) in toluene (5 mL) was added dropwise. The bath was warmed to room temperature overnight. After 15 h, the reaction was quenched with an aqueous solution of NH_4Cl (10 mL) and the mixture extracted with AcOEt (15 mL). The organic layers were dried with $MgSO_4$ and concentrated under vacuum. The crude product was purified on silica gel (petroleum ether/AcOEt, 90:10) to give the corresponding propargylamine.

Benzyl[1-(trifluoromethyl)-3-(trimethylsilyl)prop-2-ynyl]amine (4a): Compound **1** (1.1 g, 6.0 mmol) was treated with (trimethylsilyl)-acetylene (1.0 mL, 7.2 mmol) and *n*BuLi (1.6 M, 4.5 mL, 7.2 mmol). The crude material was purified on silica gel to give **4a** (1.1 g, 83%) as a brown oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.14 [s, 9 H, $Si(CH_3)_3$], 3.79 (q, J = 6.7 Hz, 1 H, C*H*CF_3), 3.83 (d, J = 12.9 Hz, 1 H, CH_2Ph), 3.97 (d, J = 12.9 Hz, 1 H, CH_2Ph), 7.04–7.32 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = –0.44 [$Si(CH_3)_3$], 50.8 (*C*H_2Ph), 52.5 (q, J = 33 Hz, *C*HCF_3), 92.1 (C), 97.3 (C), 123.8 (q, J = 281 Hz, CF_3), 127.4 (CH), 128.3 (CH), 128.5 (CH), 138.5 (C) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.5 (d, J = 6.7 Hz, 3 F) ppm. $C_{14}H_{18}F_3NSi$ (285.38): calcd. C 58.92, H 6.36, N 4.91; found C 59.01, H 6.35, N 5.15.

Benzyl[1-(trifluoromethyl)hept-2-ynyl]amine (4b): Compound **1** (611 mg, 3.3 mmol) was treated with hexyne (450 µL, 3.9 mmol) and *n*BuLi (1.6 M, 2.45 mL, 3.9 mmol). The crude material was purified on silica gel to give **4b** (830 mg, 94%) as an orange oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 1.20 (t, J = 7.1 Hz, 3 H, CH_3), 1.60–1.97 (m, 5 H, CH_2), 2.52 (td, J = 6.8, 2.0 Hz, 2 H, CH_2C), 4.12 (q, J = 6.7 Hz, 1 H, C*H*CF_3), 4.17 (d, ^1J = 13.0 Hz, 1 H, CH_2Ph), 4.31 (d, J = 13.0 Hz, 1 H, CH_2Ph), 7.50–7.67 (m, 5 H, Ar) ppm. ^{13}H NMR (75 MHz, $CDCl_3$, 25 °C): δ = 13.3 (CH_3), 18.1 (CH_2), 21.8 (CH_2), 30.4 (CH_2), 50.8 (CH_2), 52.0 (q, J = 32 Hz, *C*HCF_3), 72.5 (C), 87.2 (C), 124.1 (q, J = 281 Hz, CF_3), 127.3 (CH_{Ar}), 128.2 (CH_{Ar}), 128.4 (CH_{Ar}), 138.8 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.9 (d, J = 6.7 Hz, 3 F) ppm. $C_{15}H_{18}F_3N$ (269.31): calcd. C 66.90, H 6.74, N 5.20; found C 66.93, H 6.88, N 5.14.

Benzyl[3-phenyl-1-(trifluoromethyl)prop-2-ynyl]amine (4c): Compound **1** (568 mg, 3.0 mmol) was treated with phenylacetylene (400 µL, 3.6 mmol) and *n*BuLi (1.6 M, 2.3 mL, 3.6 mmol). The crude material was purified on silica gel to give **4c** (760 mg, 87%) as an orange oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 1.74 (br. s, 1 H, NH), 3.91 (d, J = 13.1 Hz, 1 H, CH_2Ph), 4.03 (q, J = 6.7 Hz, 1 H, C*H*CF_3), 4.04 (d, J = 13.1 Hz, 1 H, CH_2Ph), 7.06–7.44 (m, 10 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 50.9 (CH_2), 52.5 (q, J = 33 Hz, *C*HCF_3), 81.3 (C), 86.3 (C), 121.7 (C_{Ar}), 124.0 (q, J = 281 Hz, CF_3), 127.4 (CH_{Ar}), 128.2 (CH_{Ar}), 128.3 (CH_{Ar}), 128.5 (CH_{Ar}), 128.9 (CH_{Ar}), 131.8 (CH_{Ar}), 138.5 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.4 (d, J = 6.7 Hz, 3 F) ppm. $C_{17}H_{14}F_3N$ (289.30): calcd. C 70.58, H 4.88, N 4.84; found C 70.64, H 4.92, N 4.72.

(4-Methoxyphenyl)[1-(trifluoromethyl)-3-(trimethylsilyl)prop-2-ynyl]-amine (5a): Compound **2** (2.4 g, 12 mmol) was treated with (trimethylsilyl)acetylene (2.0 mL, 14 mmol) and *n*BuLi (2.5 M, 5.7 mL, 14 mmol). The crude material was purified on silica gel to give **5a** (2.6 g, 84%) as brown crystals. M.p. 60 °C (Et_2O). ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.17 [s, 9 H, $Si(CH_3)_3$], 3.66 (d, J = 9.7 Hz, 1 H, NH), 3.75 (s, 3 H, OCH_3), 4.52 (dq, J = 9.7, 6.5 Hz, 1 H, C*H*CF_3), 6.50–6.67 (m, 4 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = –0.5 [$Si(CH_3)_3$], 52.2 (q, J = 34 Hz, *C*HCF_3), 55.6 (OCH_3), 92.2 (C), 96.7 (C), 114.8 (CH_{Ar}), 116.8 (CH_{Ar}), 123.6 (q, J = 282 Hz, CF_3), 139.0 (C_{Ar}), 154.1 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –76.2 (d, J = 6.5 Hz, 3 F) ppm. $C_{14}H_{18}F_3NOSi$ (301.38): calcd. C 55.79, H 6.02, N 4.65; found C 56.05, H 6.24, N 4.62.

(4-Methoxyphenyl)[1-(trifluoromethyl)hept-2-ynyl]amine (5b): Compound **2** (1.0 g, 5.1 mmol) was treated with hexyne (700 µL, 6.1 mmol) and *n*BuLi (1.6 M, 5.4 mL, 6.1 mmol). The crude material was purified on silica gel to give **5b** (982 mg, 71%) as a brown oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.90 (t, J = 7.0 Hz, 3 H, CH_3), 1.25–1.60 (m, 4 H, 2 CH_2), 2.20 (td, J = 6.9, 1.9 Hz, 2 H, CH_2C), 3.60 (br. s, 1 H, NH), 3.76 (s, 3 H, OCH_3), 4.50 (br. q, J = 6.2 Hz, 1 H, C*H*CF_3), 6.88–7.07 (m, 4 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 13.1 (CH_3), 18.0 (CH_2), 21.6 (CH_2), 30.1 (CH_2), 51.3 (q, J = 34 Hz, *C*HCF_3), 55.2 (OCH_3), 72.1 (C), 87.1 (C), 114.6 (CH_{Ar}), 116.4 (CH_{Ar}), 123.9 (q, J = 283 Hz, CF_3), 139.1 (C_{Ar}), 153.9 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –76.6 (d, J = 6.4 Hz, 3 F) ppm. $C_{15}H_{18}F_3NO$ (285.30): calcd. C 63.15, H 6.36, N 4.91; found C 62.95, H 6.49, N 4.82.

(4-Methoxyphenyl)[3-phenyl-1-(trifluoromethyl)prop-2-ynyl]amine (5c): Compound **2** (4.0 g, 20 mmol) was treated with phenylacetylene (2.6 mL, 24 mmol) and *n*BuLi (1.6 M, 14.8 mL, 24 mmol). The crude material was purified on silica gel to give **5c** (4.7 g, 78%) as a brown oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 3.76 (s, 3 H, OCH_3), 3.91 (d, J = 9.7 Hz, 1 H, NH), 4.75 (dq, J = 9.7, 6.3 Hz, 1 H, C*H*CF_3), 6.75–6.86 (m, 4 H, Ar), 7.15–7.49 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 51.9 (q, J = 34 Hz, *C*HCF_3), 55.2 (OCH_3), 80.8 (C), 86.2 (C), 114.7 (CH_{Ar}), 116.7 (CH_{Ar}), 121.3 (C_{Ar}), 123.8 (q, J = 282 Hz, CF_3), 128.2 (CH_{Ar}), 129.0 (CH_{Ar}), 131.8 (CH_{Ar}), 138.8 (C_{Ar}), 154.1 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –76.1 (d, J = 6.3 Hz, 3 F) ppm. $C_{17}H_{14}F_3NO$ (305.30): calcd. C 68.88, H 4.62, N 4.59; found C 68.51, H 4.65, N 4.24.

(–)-[(*R*)-2-Methoxy-1-phenylethyl][(*R*)-1-(trifluoromethyl)-3-(trimethylsilyl)prop-2-ynyl]amine (6a): Compound **3** (1.1 g, 4.6 mmol) was treated with (trimethylsilyl)acetylene (780 µL, 5.5 mmol) and *n*BuLi (1.6 M, 3.5 mL, 5.5 mmol). The crude material was purified on silica gel to give **6a** (1.4 g, 95%) as an orange oil. $[\alpha]_D^{22}$ = –6 (c = 0.31, MeOH). ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.23 [s, 9 H, $Si(CH_3)_3$], 2.44 (d, J = 12 Hz, 1 H, NH), 3.41 (s, 3 H, OCH_3), 3.46 (d, J = 6.3 Hz, 1 H, CH_2O), 3.46 (d, J = 7.6 Hz, 1 H, CH_2O),

3.67 (dq, *J* = 12, 6.7 Hz, 1 H, C*H*CF_3), 4.29 (dd, *J* = 7.6, 6.3 Hz, 1 H, C*H*Ar), 7.17–7.47 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = –0.36 (CH_3), 50.9 (q, *J* = 33 Hz, *C*HCF_3), 58.2 (OCH_3), 59.1 (CHAr), 77.1 (OCH_2), 91.6 (C), 97.7 (C), 123.6 (q, *J* = 280 Hz, CF_3), 127.8 (C_{Ar}), 128.1 (CH_{Ar}), 128.7 (CH_{Ar}), 138.2 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.7 (d, *J* = 6.7 Hz, 3 F) ppm. $C_{16}H_{22}F_3NOSi$ (329.43): calcd. C 58.33, H 6.73, N 4.25; found C 58.18, H 7.05, N 3.96.

(–)-[(*R*)-2-Methoxy-1-phenylethyl][(*R*)-1-(trifluoromethyl)hept-2-ynyl]amine (6b): Compound **3** (807 mg, 3.5 mmol) was treated with hexyne (480 μL, 4.2 mmol) and *n*BuLi (1.6 M, 2.6 mL, 3.9 mmol). The crude material was purified on silica gel to give **6b** (830 mg, 77%) as an orange oil. $[\alpha]_D^{22}$ = –185 (*c* = 0.55, MeOH). ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.83 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.24–1.51 (m, 4 H, 2 CH_2), 2.14 (td, *J* = 6.8, 1.9 Hz, 2 H, CH_2C), 2.32 (br. s, 1 H, NH), 3.29 (s, 3 H, OCH_3), 3.29–3.37 (m, 2 H, CH_2O), 3.51 (qt, *J* = 6.9, 2.0 Hz, 1 H, C*H*CF_3), 4.16 (dd, *J* = 7.5, 5.9 Hz, 1 H, C*H*Ar), 7.12–7.37 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 13.3 (CH_3), 18.1 (CH_2), 21.7 (CH_2), 30.4 (CCH_2), 50.3 (q, *J* = 32 Hz, *C*HCF_3), 58.2 (OCH_3), 59.3 (CHAr), 72.7 (C), 77.1 (OCH_2), 86.7 (C), 123.9 (q, *J* = 280 Hz, CF_3), 127.7 (CH_{Ar}), 128.0 (CH_{Ar}), 128.5 (CH_{Ar}), 138.4 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –76.2 (d, *J* = 6.9 Hz, 3 F) ppm. $C_{17}H_{22}F_3NO$ (313.36): calcd. C 65.16, H 7.08, N 4.47; found C 65.33, H 7.25, N 4.39.

(–)-[(*R*)-2-Methoxy-1-phenylethyl][(*R*)-3-phenyl-1-(trifluoromethyl)-prop-2-ynyl]amine (6c): Compound **3** (654 mg, 2.8 mmol) was treated with phenylacetylene (375 μL, 3.4 mmol) and *n*BuLi (1.6 M, 2.1 mL, 3.4 mmol). The crude material was purified on silica gel to give **6c** (848 mg, 90%) as white crystals. M.p. 57 °C (Et_2O). $[\alpha]_D^{22}$ = –302 (*c* = 0.65, MeOH). ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 2.54 (d, *J* = 12.6 Hz, 1 H, NH), 3.41 (s, 3 H, OCH_3), 3.47 (d, *J* = 7.3 Hz, 1 H, OCH_2), 3.47 (d, *J* = 6.3 Hz, 1 H, OCH_2), 3.88 (dq, *J* = 12.6, 6.8 Hz, 1 H, $CHCF_3$), 4.34 (t, *J* = 6.8 Hz, 1 H, CHAr), 7.08–7.78 (m, 10 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 50.9 (q, *J* = 33 Hz, *C*HCF_3), 58.4 (OCH_3), 59.5 (CHAr), 77.2 (CH_2), 81.7 (C), 86.1 (C), 121.9 (C_{Ar}), 123.8 (q, *J* = 280 Hz, CF_3), 127.9 (CH_{Ar}), 128.2 (CH_{Ar}), 128.3 (CH_{Ar}), 128.7 (CH_{Ar}), 128.8 (CH_{Ar}), 132.0 (CH_{Ar}), 138.3 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.7 (d, *J* = 6.8 Hz, 3 F) ppm. $C_{19}H_{18}F_3NO$ (333.34): calcd. C 68.46, H 5.44, N 4.20; found C 68.38, H 5.52, N 4.14.

General Procedure for the Hydroboration Reaction: BH_3·Me_2S (2 M in THF, 5 mmol) was added under argon to cyclohexene (10 mmol) at 0 °C. The mixture was stirred for 45 min, and then the propargylamine (1 mmol) in THF (7 mL) was added dropwise. After 2.5 h, acetic acid (1 mL) was added to the mixture, and the solution was stirred at room temperature for 10 h. The reaction mixture was then successively washed with aqueous solutions of NaCl (10 mL) and $NaHCO_3$ (10 mL), and extracted with AcOEt (15 mL). The organic layers were dried with $MgSO_4$ and concentrated under vacuum. The crude product was purified on silica gel (petroleum ether/AcOEt, 90:10) to give the corresponding (*Z*)-allylamine.

Benzyl[(*Z*)-1-(trifluoromethyl)-3-(trimethylsilyl)allyl]amine (7a): Compound **4a** (248 mg, 0.9 mmol) was treated with BH_3·Me_2S (2.2 mL, 4.3 mmol) and cyclohexene (880 μL, 8.7 mmol). The crude material was purified on silica gel to give **7a** (230 mg, 92%) as an orange oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.06 [s, 9 H, $Si(CH_3)_3$], 3.77 (dq, *J* = 8.3, 7.0 Hz, 1 H, $CHCF_3$), 3.79 (d, *J* = 13.5 Hz, 1 H, C*H*$_2$Ph), 3.92 (d, *J* = 13.5 Hz, 1 H, C*H*$_2$Ph), 5.98 (d, *J* = 14.2 Hz, 1 H, CH=C*H*Si), 6.10 (dd, *J* = 14.2, 8.3 Hz, 1 H, C*H*=CHSi), 7.27–7.35 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = –0.2 [$Si(CH_3)_3$], 50.8 (CH_2Ph), 60.6 (q, *J* = 28 Hz, $CHCF_3$), 125.7 (q, *J* = 295 Hz, CF_3), 127.3 (CH_{Ar}), 128.1 (CH_{Ar}), 128.5 (CH_{Ar}), 138.6 (CH=CHSi), 139.1 (d, *J* = 1.7 Hz, *C*H=CHSi), 139.2 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –74.7 (d, *J* = 7.0 Hz, 3 F) ppm. $C_{14}H_{20}F_3NSi$ (287.40): calcd. C 58.51, H 7.01, N 4.87; found C 58.71, H 7.21, N 4.57.

Benzyl[(*Z*)-1-(trifluoromethyl)hept-2-enyl]amine (7b): Compound **4b** (270 mg, 1 mmol) was treated with BH_3·Me_2S (2.5 mL, 5 mmol) and cyclohexene (1 mL, 10 mmol). The crude material was purified on silica gel to give **7a** (253 mg, 93%) as a yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.80 (t, *J* = 7.0 Hz, 3 H, CH_3), 1.09–1.97 (m, 6 H, 2 CH_2), 3.70 (d, *J* = 13.4 Hz, 1 H, C*H*$_2$Ph), 3.84 (d, *J* = 13.4 Hz, 1 H, C*H*$_2$Ph), 3.81 (dq, *J* = 9.6, 7.2 Hz, 1 H, C*H*CF_3), 5.20 (dd, *J* = 11.0, 9.6 Hz, 1 H, C*H*=$CHCH_2$), 5.73 (dt, *J* = 11.0, 7.5 Hz, 1 H, CH=C*H*CH_2), 7.16–7.31 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 13.7 (CH_3), 22.2 (CH_3CH_2), 27.6 (CH_2), 31.3 ($CHCH_2$), 50.8 (*C*H$_2$Ph), 55.7 (q, *J* = 29 Hz, *C*HCF_3), 122.2 (*C*H=$CHCH_2$), 125.8 (q, *J* = 281 Hz, CF_3), 127.2 (CH_{Ar}), 128.1 (CH_{Ar}), 128.4 (CH_{Ar}), 137.9 (CH=*C*HCH_2), 139.2 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.4 (d, *J* = 7.2 Hz, 3 F) ppm. $C_{15}H_{20}F_3N$ (271.32): calcd. C 66.40, H 7.43, N 5.16; found C 66.19, H 7.58, N 5.02.

(4-Methoxyphenyl)[(*Z*)-1-(trifluoromethyl)-3-(trimethylsilyl)allyl]-amine (8a): Compound **5a** (283 mg, 0.9 mmol) was treated with BH_3·Me_2S (2.3 mL, 4.7 mmol) and cyclohexene (950 μL, 9.4 mmol). The crude material was purified on silica gel to give **8a** (101 mg, 35%) as an orange oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.11 [s, 9 H, $Si(CH_3)_3$], 3.75 (s, 3 H, OCH_3), 4.29 (dq, *J* = 8.5, 6.8 Hz, 1 H, C*H*CF_3), 5.88 (d, *J* = 14.2 Hz, 1 H, CH=C*H*Si), 6.07 (dd, *J* = 14.2, 8.5 Hz, 1 H, C*H*=CHSi), 6.50–6.74 (m, 4 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = –0.2 [$Si(CH_3)_3$], 55.6 (OCH_3), 59.6 (q, *J* = 30 Hz, *C*HCF_3), 114.8 (CH_{Ar}), 116.3 (q, *J* = 0.8 Hz, CH_{Ar}), 125.4 (q, *J* = 283 Hz, C_{Ar}), 138.0 (q, *J* = 2.0 Hz, *C*H=CHSi), 138.4 (CH=*C*HSi), 139.6 (C_{Ar}), 153.5 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.4 (d, *J* = 6.8 Hz, 3 F) ppm. $C_{14}H_{20}F_3NOSi$ (303.37): calcd. C 55.42, H 6.64, N 4.62; found C 55.23, H 6.53, N 4.51.

(4-Methoxyphenyl)[(*Z*)-3-phenyl-1-(trifluoromethyl)allyl]amine (8c): Compound **5c** (263 mg, 0.9 mmol) was treated with BH_3·Me_2S (2.2 mL, 4.3 mmol) and cyclohexene (870 μL, 8.6 mmol). The crude material was purified on silica gel to give **8c** (85 mg, 32%) as a yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 3.72 (s, 3 H, OCH_3), 4.73 (dq, *J* = 9.8, 6.6 Hz, 1 H, C*H*CF_3), 5.64 (dd, *J* = 11.3, 9.8 Hz, 1 H, C*H*=CHPh), 6.41–6.75 (m, 4 H, Ar), 6.88 (d, *J* = 11.3 Hz, 1 H, CH=C*H*Ph), 7.14–7.39 (m, 5 H, Ph) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 55.0 (q, *J* = 30 Hz, *C*HCF_3), 55.6 (OCH_3), 114.8 (CH_{Ar}), 115.7 (CH_{Ar}), 123.3 (*C*H=CHPh), 126.1 (q, *J* = 282 Hz, CF_3), 127.9 (CH_{Ar}), 128.4 (CH_{Ar}), 128.5 (CH_{Ar}), 135.5 (C_{Ar}), 136.1 (CH=*C*HPh), 139.0 (C_{Ar}), 153.3 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.1 (d, *J* = 6.6 Hz, 3 F) ppm. $C_{17}H_{16}F_3NO$ (307.31): calcd. C 66.44, H 5.25, N 5.56; found C 66.56, H 5.43, N 5.37.

(–)-[(*R*)-2-Methoxy-1-phenylethyl][(*R*,*Z*)-1-(trifluoromethyl)hept-2-enyl]amine (9b): Compound **6b** (211 mg, 0.7 mmol) was treated with BH_3·Me_2S (1.7 mL, 3.4 mmol) and cyclohexene (680 μL, 6.7 mmol). The crude material was purified on silica gel to give **9b** (182 mg, 86%) as a colorless oil. $[\alpha]_D^{22}$ = –6 (*c* = 0.80, MeOH). ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.73 (t, *J* = 7.1 Hz, 3 H, CH_3), 1.01–1.38 (m, 4 H, 2 CH_2), 1.46–1.80 (m, 2 H, C*H*$_2$CH=), 3.22–3.33 (m, 2 H, C*H*$_2$CHPh), 3.25 (s, 3 H, OCH_3), 3.56 (dq, *J* = 9.5, 7.6 Hz, 1 H, C*H*CF_3), 3.86 (dd, *J* = 8.5, 4.8 Hz, 1 H, C*H*Ph), 5.13 (br. t, *J* = 10.4 Hz, 1 H, CH=C*H*CH_2), 5.72 (dt, *J* = 10.9,

7.4 Hz, 1 H, C*H*=CHCH$_2$), 7.08–7.38 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, CDCl$_3$, 25 °C): δ = 13.7 (CH$_3$), 22.1 (*C*H$_2$CH$_3$), 27.3 (CH$_2$), 31.5 (*C*H$_2$CH=), 53.9 (q, J = 29 Hz, *C*HCF$_3$), 58.5 (OCH$_3$), 58.7 (*C*HPh), 77.5 (OCH$_2$), 122.4 (CH=*C*HCH$_2$), 125.5 (q, J = 280 Hz, CF$_3$), 127.8 (CH$_{Ar}$), 128.5 (CH$_{Ar}$), 137.8 (C*H*=CHCH$_2$), 139.2 (C$_{Ar}$) ppm. ^{19}F NMR (188 MHz, CDCl$_3$, 25 °C): δ = –75.7 (d, J = 7.6 Hz, 3 F) ppm. $C_{17}H_{24}F_3NO$ (315.37): calcd. C 64.74, H 7.67, N 4.44; found C 64.49, H 7.92, N 4.32.

(–)-[(*R*)-2-Methoxy-1-phenylethyl][(*R*,*Z*)-3-phenyl-1-(trifluoromethyl)allyl]amine (9c): Compound **6c** (337 mg, 1 mmol) was treated with BH$_3$·Me$_2$S (205 mL, 5 mmol) and cyclohexene (1 mL, 10 mmol). The crude material was purified on silica gel to give **9c** (285 mg, 85%) as a yellow solid. M.p. 72 °C. $[a]_D^{22}$ = –21 (c = 0.24, MeOH). ^{1}H NMR (200 MHz, CDCl$_3$, 25 °C): δ = 2.2 (s, 1 H, NH), 3.47–3.52 (m, 2 H, OCH$_2$), 3.51 (s, 3 H, OCH$_3$), 3.9 (dd, J = 8.6, 4.8 Hz, 1 H, NHC*H*), 4.0 (qd, J = 10.3, 7.5 Hz, 1 H, C*H*CF$_3$), 5.7 (t, J = 11.0 Hz, 1 H, C*H*=CHPh), 7.0–7.4 (m, CH=C*H*Ph, 11 H, 2 Ar) ppm. ^{13}C NMR (75 MHz, CDCl$_3$, 25 °C): δ = 53.9 (q, J = 29 Hz, *C*HCF$_3$), 58.5 (OCH$_3$), 58.7 (*C*HPh), 77.0 (OCH$_2$), 124.2 (CH=*C*HPh), 125.6 (q, J = 280 Hz, CF$_3$), 127.3, (C$_{Ar}$) 127.4 (C$_{Ar}$), 128.0 (C$_{Ar}$), 128.18 (C$_{Ar}$), 128.2 (C$_{Ar}$), 135.6 (C$_{Ar}$), 135.9 (*C*H=CHPh), 138.4 (C$_{Ar}$) ppm. ^{19}F NMR (188 MHz, CDCl$_3$, 25 °C): δ = –74.86 (d, J = 7.6 Hz, 3 F) ppm. $C_{19}H_{20}F_3NO$ (335.37): calcd. C 68.05, H 6.01, N 4.18; found C 67.90, H 6.12, N 4.22.

General Procedure for the Hydroalumination Reaction: LiAlH$_4$ (4 mmol) was added in one portion to a solution of the propargylamine (1 mmol) in THF (10 mL) at room temperature. The reaction mixture was immediately heated to reflux in THF (oil bath preheated) and stirred for 2 h. The solution was cooled to room temperature, diluted with AcOEt (10 mL) and filtered through Celite. The solution was washed with an aqueous solution of NH$_4$Cl (10 mL), dried with MgSO$_4$ and concentrated under vacuum. The crude product was purified on silica gel (cyclohexane/AcOEt, 90:10) to give the corresponding (*E*)-allylamine.

Benzyl[(*E*)-1-(trifluoromethyl)hept-2-enyl]amine (12b): Compound **4a** (271 mg, 1.0 mmol) was treated with LiAlH$_4$ (153 mg, 4.0 mmol). The crude material was purified on silica gel to give **12b** (257 mg, 94%) as a yellow oil. ^{1}H NMR (200 MHz, CDCl$_3$, 25 °C): δ = 0.91 (t, J = 7.0 Hz, 3 H, CH$_3$), 1.22–1.49 (m, 4 H, 2 CH$_2$), 1.67 (br. m, 1 H, NH), 2.11 (q, J = 7.0 Hz, 2 H, C*H*$_2$CH=), 3.51 (q, J = 7.6 Hz, 1 H, C*H*CF$_3$), 3.77 (d, J = 13.5 Hz, 1 H, C*H*$_2$Ph), 3.91 (d, J = 13.5 Hz, 1 H, C*H*$_2$Ph), 5.33 (dd, J = 15.5, 7.9 Hz, 1 H, C*H*=CHBu), 5.77 (dt, J = 15.5, 6.7 Hz, 1 H, CH=C*H*Bu), 7.21–7.40 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, CDCl$_3$, 25 °C): δ = 13.7 (CH$_3$), 22.1 (CH$_2$), 31.0 (CH$_2$), 32.0 (*C*H$_2$CH=), 50.6 (*C*H$_2$Ph), 61.3 (q, J = 29 Hz, *C*HCF$_3$), 122.4 (CH=*C*HBu), 125.7 (q, J = 281 Hz, CF$_3$), 127.2 (CH$_{Ar}$), 128.1 (CH$_{Ar}$), 128.4 (CH$_{Ar}$), 138.6 (q, J = 2.0 Hz, *C*H=CHBu), 139.4 (C$_{Ar}$) ppm. ^{19}F NMR (188 MHz, CDCl$_3$, 25 °C): δ = –75.5 (d, J = 7.4 Hz, 3 F) ppm. $C_{15}H_{20}F_3N$ (271.32): calcd. C 66.40, H 7.43, N 5.16; found C 66.59, H 7.15, N 4.83.

Benzyl[(*E*)-3-phenyl-1-(trifluoromethyl)allyl]amine (12c): Compound **4c** (289 mg, 1.1 mmol) was treated with LiAlH$_4$ (168 mg, 4.3 mmol). The crude material was purified on silica gel to give **12c** (262 mg, 90%) as a brown oil. ^{1}H NMR (200 MHz, CDCl$_3$, 25 °C): δ = 3.69 (q, J = 7.4 Hz, 1 H, C*H*CF$_3$), 3.80 (d, J = 13.3 Hz, 1 H, C*H*$_2$Ph), 3.93 (d, J = 13.3 Hz, 1 H, C*H*$_2$Ph), 6.04 (dd, J = 16.0, 7.0 Hz, 1 H, C*H*=CHPh), 6.63 (d, J = 16.0 Hz, 1 H, CH=C*H*Ph), 7.19–7.44 (m, 10 H, 2 Ar) ppm. ^{13}H NMR (75 MHz, CDCl$_3$, 25 °C): δ = 50.6 (CH$_2$Ph), 61.3 (q, J = 29 Hz, *C*HCF$_3$), 121.6 (CH=*C*HPh), 125.6 (q, J = 282 Hz, CF$_3$), 126.6 (CH$_{Ar}$), 127.2 (CH$_{Ar}$), 128.0 (CH$_{Ar}$), 128.3 (CH$_{Ar}$), 128.4 (CH$_{Ar}$), 128.6 (CH$_{Ar}$), 135.7 (C$_{Ar}$), 136.3 (*C*H=CHPh), 139.1 (C$_{Ar}$) ppm. ^{19}F NMR (188 MHz, CDCl$_3$, 25 °C): δ = –75.3 (t, J = 7.4 Hz, 3 F) ppm. $C_{17}H_{16}F_3N$ (291.31): calcd. C 70.09, H 5.54, N 4.81; found C 69.97, H 5.86, N 4.72.

(4-Methoxyphenyl)[(*E*)-1-(trifluoromethyl)-3-(trimethylsilyl)allyl]amine (13a): Compound **5a** (68 mg, 0.2 mmol) was treated with LiAlH$_4$ (34 mg, 0.9 mmol). The crude material was purified on silica gel to give **13a** (60 mg, 88%) as a brown oil. ^{1}H NMR (200 MHz, CDCl$_3$, 25 °C): δ = 0.09 [s, 9 H, Si(CH$_3$)$_3$], 3.61 (br. d, J = 9.7 Hz, 1 H, NH), 3.75 (s, 3 H, OCH$_3$), 4.24–4.42 (m, 1 H, C*H*CF$_3$), 6.02 (dd, J = 18.7, 4.6 Hz, 1 H, C*H*=CHSi), 6.21 (d, J = 18.7 Hz, 1 H, CH=C*H*Si), 6.60–6.90 (m, 4 H, Ar) ppm. ^{13}C NMR (75 MHz, CDCl$_3$, 25 °C): δ = –1.6 [Si(CH$_3$)$_3$], 55.7 (OCH$_3$), 60.9 (q, J = 29 Hz, *C*HCF$_3$), 114.9 (CH$_{Ar}$), 115.5 (CH$_{Ar}$), 125.3 (q, J = 282 Hz, CF$_3$), 136.4 (CH=*C*HSi), 136.7 (*C*H=CHSi), 140.0 (C$_{Ar}$), 153.2 (C$_{Ar}$) ppm. ^{19}F NMR (188 MHz, CDCl$_3$, 25 °C): δ = –75.6 (d, J = 7.4 Hz, 3 F) ppm. $C_{14}H_{20}F_3NOSi$ (303.40): calcd. C 55.42, H 6.64, N 4.62; found C 55.61, H 6.31, N 4.32.

(4-Methoxyphenyl)[(*E*)-1-(trifluoromethyl)hept-2-enyl]amine (13b): Compound **5b** (289 mg, 1.1 mmol) was treated with LiAlH$_4$ (168 mg, 4.3 mmol). The crude material was purified on silica gel to give **13b** (259 mg, 89%) as a brown oil. ^{1}H NMR (200 MHz, CDCl$_3$, 25 °C): δ = 0.88 (t, J = 6.8 Hz, 3 H, CH$_3$), 1.18–1.51 (m, 4 H, 2 CH$_2$), 2.08 (q, J = 6.7 Hz, 2 H, C*H*$_2$CH=), 3.75 (s, 3 H, OCH$_3$), 4.26 (q, J = 6.9 Hz, 1 H, C*H*CF$_3$), 5.44 (dd, J = 15.5, 6.5 Hz, 1 H, C*H*=CHBu), 5.88 (dt, J = 15.5, 6.7 Hz, 1 H, CH=C*H*Bu), 6.61–6.82 (m, 4 H, Ar) ppm. ^{13}C NMR (75 MHz, CDCl$_3$, 25 °C): δ = 13.6 (CH$_3$), 21.9 (CH$_2$), 30.7 (CH$_2$), 31.8 (*C*H$_2$CH=), 55.4 (OCH$_3$), 59.3 (q, J = 30 Hz, *C*HCF$_3$), 114.7 (CH$_{Ar}$), 115.6 (CH$_{Ar}$), 121.8 (*C*H=CHBu), 125.4 (q, J = 282 Hz, CF$_3$), 137.6 (CH=*C*HBu), 139.8 (C$_{Ar}$), 153.1 (C$_{Ar}$) ppm. ^{19}F NMR (188 MHz, CDCl$_3$, 25 °C): δ = –76.0 (d, J = 7.1 Hz, 3 F) ppm. $C_{15}H_{20}F_3NO$ (287.32): calcd. C 62.70, H 7.02, N 4.87; found C 62.96, H 7.29, N 4.71.

(4-Methoxyphenyl)[(*E*)-3-phenyl-1-(trifluoromethyl)allyl]amine (13c): Compound **5c** (321 mg, 1.0 mmol) was treated with LiAlH$_4$ (160 mg, 4.2 mmol). The crude material was purified on silica gel to give **13c** (291 mg, 90%) as a brown oil. ^{1}H NMR (200 MHz, CDCl$_3$, 25 °C): δ = 2.1 (br. s, 1 H, NH), 3.72 (s, 3 H, OCH$_3$), 4.48 (m, 1 H, C*H*CF$_3$), 6.17 (dd, J = 15.9, 6.4 Hz, 1 H, C*H*=CHPh), 6.66–6.82 (m, 5 H, Ar and CH=C*H*Ph), 7.21–7.41 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, CDCl$_3$, 25 °C): δ = 55.2 (OCH$_3$), 59.3 (q, J = 30 Hz, *C*HCF$_3$), 114.7 (CH$_{Ar}$), 115.5 (CH$_{Ar}$), 120.9 (CH=*C*HPh), 125.3 (q, J = 282 Hz, CF$_3$), 126.5 (CH$_{Ar}$), 128.2 (CH$_{Ar}$), 128.4 (CH$_{Ar}$), 135.2 (*C*H=CHPh), 135.5 (C$_{Ar}$), 139.7 (C$_{Ar}$), 153.1 (C$_{Ar}$) ppm. ^{19}F NMR (188 MHz, CDCl$_3$, 25 °C): δ = –75.5 (d, J = 7.1 Hz, 3 F) ppm. $C_{17}H_{16}F_3NO$ (307.31): calcd. C 66.44, H 5.25, N 4.56; found C 66.53, H 5.05, N 4.19.

(–)-[(*R*)-2-Methoxy-1-phenylethyl][(*E*)-1-(trifluoromethyl)-3-(trimethylsilyl)allyl]amine (14a): Compound **6a** (387 mg, 1.2 mmol) was treated with LiAlH$_4$ (177 mg, 4.6 mmol). The crude material was purified on silica gel to give **14a** (343 mg, 88%) as a brown oil. $[a]_D^{22}$ = –95 (c = 0.63, MeOH). ^{1}H NMR (200 MHz, CDCl$_3$, 25 °C): δ = 0.00 [s, 9 H, Si(CH$_3$)$_3$], 2.07 (br. s, 1 H, NH), 3.20 (qd, J = 7.8, 5.8 Hz, 1 H, C*H*CF$_3$), 3.24 (s, 3 H, OCH$_3$), 3.29 (d, J = 5.4 Hz, 1 H, C*H*$_2$CH), 3.30 (d, J = 8.0 Hz, 1 H, C*H*$_2$CH), 3.83 (dd, J = 8.0, 5.4 Hz, 1 H, C*H*CH$_2$), 5.67 (dd, J = 18.5, 5.8 Hz, 1 H, C*H*=CHSi), 5.80 (d, J = 18.5 Hz, 1 H, CH=C*H*Si), 7.10–7.29 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, CDCl$_3$, 25 °C): δ = –1.6 [Si(CH$_3$)$_3$], 58.3 (OCH$_3$), 58.6 (*C*HPh), 61.6 (q, J = 29 Hz, *C*HCF$_3$), 77.5 (OCH$_2$), 125.3 (q, J = 280 Hz, CF$_3$), 127.8 (CH$_{Ar}$), 128.5 (CH$_{Ar}$), 136.9 (CH=CHSi), 137.8 (CH=CHSi), 139.1 (C$_{Ar}$) ppm. ^{19}F NMR

(188 MHz, $CDCl_3$, 25 °C): δ = –75.4 (d, J = 7.8 Hz, 3 F) ppm. $C_{16}H_{24}F_3NOSi$ (331.45): calcd. C 57.98, H 7.30, N 4.23; found C 58.14, H 7.43, N 3.97.

(–)-[(*R*)-2-Methoxy-1-phenylethyl][(*E*)-3-phenyl-1-(trifluoromethyl)-allyl]amine (14c): Compound **6c** (300 mg, 0.89 mmol) was treated with $LiAlH_4$ (129 mg, 3.4 mmol). The crude material was purified on silica gel to give **14c** (272 mg, 90%) as a yellow oil. $[\alpha]_D^{22}$ = –200 (c = 0.4, MeOH). ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 3.37 (s, 3 H, OCH_3), 3.41 (d, J = 6.5 Hz, 2 H, OCH_2), 3.5 (m, 1 H, C*H*CF_3), 4.0 (t, J = 6.7 Hz, 1 H, C*H*Ph), 6.0 (dd, J = 16.0, 8.5 Hz, 1 H, C*H*=CHPh), 6.47 (d, J = 16.0 Hz, 1 H, CH=C*H*Ph), 7.28–7.45 (m, 10 H, 2 Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = 58.6 (OCH_3), 58.7 (*C*HPh), 59.4 (q, J = 29 Hz, *C*HCF_3), 77.4 (OCH_2), 121.35 (CH=*C*HPh), 126.7 (C_{Ar}), 127.8 (C_{Ar}), 127.9 (C_{Ar}), 128.3 (C_{Ar}), 128.6 (C_{Ar}), 128.7 (C_{Ar}), 135.7 (C_{Ar}), 136.2 (*C*H=CHPh), 139.0 (C_{Ar}) ppm; CF_3 signal not observed. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.4 (d, J = 7.6 Hz, 3 F) ppm. $C_{19}H_{20}F_3NO$ (336.22): calcd. C 68.05, H 6.01, N 4.18; found C 68.21, H 5.95, N 4.11.

[(*E*)-2-Deuterio-1-(trifluoromethyl)-3-(trimethylsilyl)allyl](4-methoxyphenyl)amine (15-H): Compound **5a** (126 mg, 0.4 mmol) was treated with $LiAlD_4$ (70 mg, 1.7 mmol). Once the starting material had been consumed (GC), a part of the solution was hydrolyzed with H_2O to give **15-H**. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.09 [s, 9 H, $Si(CH_3)_3$], 3.58 (br. d, J = 8.0 Hz, 1 H, NH), 3.75 (s, 3 H, OCH_3), 4.33 (q, J = 7.6 Hz, 1 H, C*H*CF_3), 6.18 (s, 1 H, CD=C*H*Si), 6.60–6.90 (m, 4 H, Ar) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.6 (d, J = 7.4 Hz, 3 F) ppm.

[(*E*)-2,3-Dideuterio-1-(trifluoromethyl)-3-(trimethylsilyl)allyl](4-methoxyphenyl)amine (15-D): Compound **5a** (126 mg, 0.4 mmol) was treated with $LiAlD_4$ (70 mg, 1.7 mmol). Once the starting material had been consumed (GC), a part of the solution was hydrolyzed with D_2O to give **15-D**. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.09 [s, 9 H, $Si(CH_3)_3$], 3.61 (br. d, J = 8.9 Hz, 1 H, NH), 3.75 (s, 3 H, OCH_3), 4.33 (q, J = 7.6 Hz, 1 H, C*H*CF_3), 6.60–6.90 (m, 4 H, Ar) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –75.6 (d, J = 7.4 Hz, 3 F) ppm.

[1-(Difluoromethyl)-3-(trimethylsilyl)prop-2-ynyl](4-methoxyphenyl)amine (11a): $LiAlH_4$ (67 mg, 1.8 mmol) was added in one portion to a solution of propargylamine **5a** (133 mg, 0.4 mmol) in THF (5 mL) at room temperature. After stirring at this temperature for 1 h, the reaction was quenched with an aqueous solution of NH_4Cl (10 mL), the mixture extracted with AcOEt (10 mL), dried with $MgSO_4$ and concentrated under vacuum. The crude product was purified on silica gel (cyclohexane/AcOEt, 95:5) to give **11a** (110 mg, 88%). ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.17 [s, 9 H, $Si(CH_3)_3$], 3.76 (s, 3 H, OCH_3), 4.34 (ddd, J = 13.0, 10.0, 3.0 Hz, 1 H, HF_2CCH), 5.85 (td, J = 55.0, 3.0 Hz, 1 H, CF_2H), 6.69–6.87 (m, 4 H, Ar) ppm. ^{13}C NMR (75 MHz, $CDCl_3$, 25 °C): δ = –0.39 [$Si(CH_3)_3$], 51.4 (t, J = 25 Hz, *C*HCF_2H), 55.5 (OCH_3), 91.6 (C), 98.5 (C), 113.8 (t, J = 248 Hz, CF_2H), 114.7 (CH_{Ar}), 116.7 (CH_{Ar}), 139.3 (C_{Ar}), 153.8 (C_{Ar}) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –126.9 (ddd, J = 278, 55, 13 Hz, 1 F), –124.9 (ddd, J = 278, 55, 10 Hz, 1 F) ppm.

[1-Deuterio-1-(difluoromethyl)-3-(trimethylsilyl)prop-2-ynyl](4-methoxyphenyl)amine (16): According to the previous procedure, **5a** (191 mg, 0.6 mmol) in THF (6 mL) was treated with $LiAlD_4$ (27 mg, 0.6 mmol) at room temperature. After 2 h at this temperature, in a part of the mixture the reaction was quenched with H_2O and in the rest with D_2O. In both cases, compound **16** was obtained. ^{1}H NMR (200 MHz, $CDCl_3$, 25 °C): δ = 0.16 [s, 9 H, $Si(CH_3)_3$], 3.76 (s, 3 H, OCH_3), 5.84 (t, J = 56 Hz, 1 H, CF_2H), 6.67–6.87 (m, 4 H, Ar) ppm. ^{19}F NMR (188 MHz, $CDCl_3$, 25 °C): δ = –127.1 (dd, J = 279, 56 Hz, 1 F), –125.1 (dd, J = 279, 56 Hz, 1 F) ppm.

General Procedure for the Deprotection of the Chiral Auxiliary

(–)-[(*E*,*R*)-3-Phenyl-1-(trifluoromethyl)allyl]amine Hydrochloride (17c): Boron tribromide (1.5 mL, 1 M in CH_2Cl_2, 1.5 mmol) was added dropwise to a solution of **14c** (160 mg, 0.5 mmol) in dry CH_2Cl_2 (6 mL) at –20 °C under argon. After stirring at –20 °C for 45 min, the reaction was quenched with a saturated aqueous solution of $NaHCO_3$ (10 mL) and the mixture extracted with ethyl acetate (3 × 10 mL). The combined organic layers were washed with brine, dried with anhydrous $MgSO_4$, filtered and concentrated under reduced pressure to give a clean crude product of the corresponding alcohol (160 mg, 96%) which was used directly in the next reaction. $Pb(OAc)_4$ (310 mg, 0.7 mmol) was added to a solution of the alcohol (160 mg, 0.5 mmol) in a 2:1 mixture of MeOH/CH_2Cl_2 (10 mL) at 0 °C. After 30 min of stirring at 0 °C, the reaction mixture was poured into an aqueous buffer solution (pH = 7, 10 mL) at room temperature and then filtered through Celite. The aqueous layer was extracted with dichloromethane (4 × 10 mL), and the combined organic extracts were dried with Na_2SO_4, filtered and concentrated under reduced pressure. HCl (3 N, 5 mL) was then added. After 24 h at room temperature, the reaction mixture was extracted with diethyl ether (3 × 5 mL), and the combined aqueous extracts were concentrated under reduced pressure to afford (*R*)-allylamine **17c**. The hydrochloride was dissolved in propylene oxide (10 mL) and stirred at room temperature for 1 h. The crude mixture was concentrated under reduced pressure, and pure **17c** (94 mg, 80%) was obtained after recrystallization in methanol/diethyl ether. $[\alpha]_D^{25}$ = –50 (c = 0.2, MeOH). ^{1}H NMR (200 MHz, CD_3OH, 25 °C): δ = 4.95 (quint, 1 H, C*H*CF_3), 5.5 (br. s, 3 H, NH_3), 6.2 (dd, J = 8.8, 15.8 Hz, 1 H, C*H*=CHPh), 7.14 (d, J = 15.8 Hz, 1 H, CH=C*H*Ph), 7.4 (m, 3 H, Ar), 7.54 (m, 2 H, Ar) ppm. ^{13}H NMR (75 MHz, CD_3OD, 25 °C): δ = 55.8 (q, J = 33 Hz, *C*HCF_3), 115.0 (CH=*C*HPh), 124.8 (q, J = 280 Hz, CF_3), 128.3 (CH_{Ar}), 130.0 (CH_{Ar}), 130.7 (CH_{Ar}), 135.9 (C_{Ar}), 143.1 (*C*H=CHPh) ppm. ^{19}F NMR (188 MHz, CD_3OD, 25 °C): δ = –75.5 (d, J = 6.7 Hz, 3 F) ppm. $C_{10}H_{11}ClF_3N$ (237.65): calcd. C 50.75, H 4.26, N 5.92; found C 50.62, H 4.10, N 6.14.

(+)-[(*R*,*Z*)-3-Phenyl-1-(trifluoromethyl)allyl]amine Hydrochloride (18c): Boron tribromide (1.35 mL, 1 M in CH_2Cl_2, 1.34 mmol) was added dropwise to a solution of **9c** (150 mg, 0.45 mmol) in dry CH_2Cl_2 (6 mL) at –20 °C under argon. After stirring at –20 °C for 45 min, the reaction was quenched with a saturated aqueous solution of $NaHCO_3$ (10 mL) and extracted with ethyl acetate (3 × 10 mL). The combined organic layers were washed with brine, dried with anhydrous $MgSO_4$, filtered and concentrated under reduced pressure to give a clean crude product of the corresponding alcohol (154 mg) which was used directly in the next reaction. $Pb(OAc)_4$ (300 mg, 0.67 mmol) was added to a solution of the alcohol (154 mg, 0.48 mmol) in a 2:1 mixture of MeOH/CH_2Cl_2 (10 mL) at 0 °C. After 30 min of stirring at 0 °C, the reaction mixture was poured into an aqueous buffer solution (pH = 7, 10 mL) at room temperature and then filtered through Celite. The aqueous layer was extracted with dichloromethane (4 × 10 mL), and the combined organic extracts were dried with Na_2SO_4, filtered and concentrated under reduced pressure. HCl (3 N, 5 mL) was then added. After 24 h at room temperature, the reaction mixture was extracted with diethyl ether (3 × 5 mL), and the combined aqueous extracts were concentrated under reduced pressure to afford (*R*)-allylamine **18c**. The hydrochloride was dissolved in propylene oxide (10 mL) and stirred at room temperature for 1 h. The crude mixture

was concentrated under reduced pressure and pure **18c** (116 mg, 77%) was obtained after recrystallization in methanol/ether. $[a]_D^{25}$ = +20 (*c* = 0.1, MeOH). ^{1}H NMR (200 MHz, CD_3OD, 25 °C): δ = 4.8–5.1 (m, 4 H, NH_3, C*H*CF_3), 5.75 (t, *J* = 11.0 Hz, 1 H, C*H*=CHPh), 7.28 (d, *J* = 11.0 Hz, 1 H, CH=C*H*Ph), 7.34–7.50 (m, 5 H, Ar) ppm. ^{13}C NMR (75 MHz, CD_3OD, 25 °C): δ = 51.3 (q, *J* = 33 Hz, *C*HCF_3), 117.3 (*C*H=CHPh), 124.8 (q, *J* = 280 Hz, CF_3), 129.4 (CH_{Ar}), 130.0 (CH_{Ar}), 130.1 (C_{Ar}), 135.5 (C_{Ar}), 143.1 (CH=*C*HPh) ppm. ^{19}F NMR (188 MHz, CD_3OD, 25 °C): δ = –75.4 (d, *J* = 6.7 Hz, 3 F) ppm. $C_{10}H_{11}ClF_3N$ (237.65): calcd. C 50.75, H 4.26, N 5.92; found C 50.94, H 4.35, N 6.03.

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