Copper-Catalyzed Decarboxylative Trifluoromethylation of Propargyl Bromodifluoroacetates

Brett R. Ambler,[a] Santosh Peddi,[b] Ryan A. Altman*[a]

[a] Department of Medicinal Chemistry, The University of Kansas, 1251 Wescoe Hall Drive, Lawrence, KS 66045, USA

[b] Department of Pharmacy, Birla Institute of Technology & Science, Pilani–Hyderabad Campus, Jawahar Nagar, Shameerpet Mandal, Hyderabad, 500078 Andhra Pradesh, India
Fax +1(785)8645326; E-mail: raaltman@ku.edu

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Abstract: The development of efficient methods for accessing fluorinated functional groups is desirable. Herein, we report a two-step method that utilizes catalytic copper for the decarboxylative trifluoromethylation of propargyl bromodifluoroacetates is described. This protocol affords a mixture of propargyl trifluoromethanes and trifluoromethyl allenes.

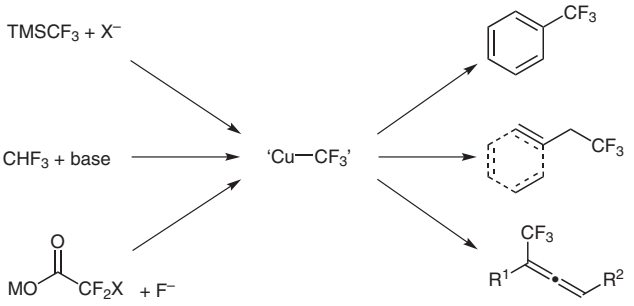
Key words: copper, catalysis, trifluoromethylation, decarboxylation, alkynes

The development of methods that enable the incorporation of the trifluoromethyl group into organic compounds can impact agricultural chemistry,[1] chemical biology,[2] materials science,[3] and medicinal chemistry.[2] Among the numerous approaches for trifluoromethylation,[4] copper(0) and copper salts are frequently employed to both generate and harness reactive trifluoromethyl (CF_3) complexes. In recent years, improved methods have enabled the generation of copper–trifluoromethyl (Cu–CF_3) species from common starting materials, including R_3Si–CF_3,[5] trifluoromethane (CHF_3),[6] halodifluoroacetates,[7] and *S*-(trifluoromethyl)diarylsulfonium salts.[8] In these reactions, Cu–CF_3 complexes typically display excellent functional group compatibility, and can be used in the presence of hard electrophiles such as aldehydes and ketones.[6] Further, these species tolerate high temperatures[7b–f] and the presence of protic solvents, including water.[9]

Given these benefits, the reaction of Cu–CF_3 species[10] with activated electrophiles can provide trifluoromethanes under mild conditions. A range of allyl, benzyl, propargyl and aromatic electrophiles react with Cu–CF_3 complexes to provide trifluoromethane-containing products (Scheme 1).[5–8] While the use of stoichiometric copper enables a variety of important transformations,[4] the principles of green chemistry encourage the development of trifluoromethylation reactions that only utilize catalytic quantities of copper.[11]

The conversion of propargyl electrophiles (bromides, chlorides, mesylates, and trifluoroacetates) into trifluoromethanes represents one such transformation. Several methods that utilize stoichiometric quantities of Cu–CF_3 complexes have been reported (Scheme 2, eq 1–3).[12] Depending upon the nature of the substrate and the Cu–CF_3 species, two classes of products were obtained: propargyl trifluoromethanes and trifluoromethyl allenes. Most commonly, primary propargyl electrophiles yielded propargyl trifluoromethanes (Scheme 2, eq 1), whereas secondary substrates provided trifluoromethyl allenes (Scheme 2, eq 2).[12] Propargyl trifluoromethanes were also accessed from secondary propargyl chlorides, however, the reaction proceeded via the initial formation of trifluoromethyl allene, followed by a rearrangement that afforded a propargyl trifluoromethane (Scheme 2, eq 3).[12b] In addition to these copper-mediated reactions, an alternative copper-catalyzed trifluoromethylation employed copper(I) thiophene-2-carboxylate (CuTC) and trimethyl(trifluoromethyl)silane (TMS–CF_3) with potassium fluoride (KF) as an activator (Scheme 2, eq 4 and 5).[13] The regioselectivity of this transformation was dictated by the substrate, with primary propargyl chlorides providing propargyl trifluoromethanes (Scheme 2, eq 4), and secondary propargyl chlorides affording trifluoromethyl allenes (Scheme 2, eq 5).[13]

In contrast, alternative electrophiles for nucleophilic substitution include propargyl halodifluoroacetates, which undergo decarboxylative trifluoromethylation upon treatment with stoichiometric copper(I) iodide (CuI).[14] However, only a single example of this transformation exists, which converts propargyl chlorodifluoroacetate into trifluoromethyl allene (Scheme 2, eq 6).[14] While this strategy utilized decarboxylation as an effective method to generate reactive fluorinated species, the use of stoichio-



Scheme 1 Generation of Cu–CF_3 from various reagents enables the synthesis of trifluoromethane-containing products

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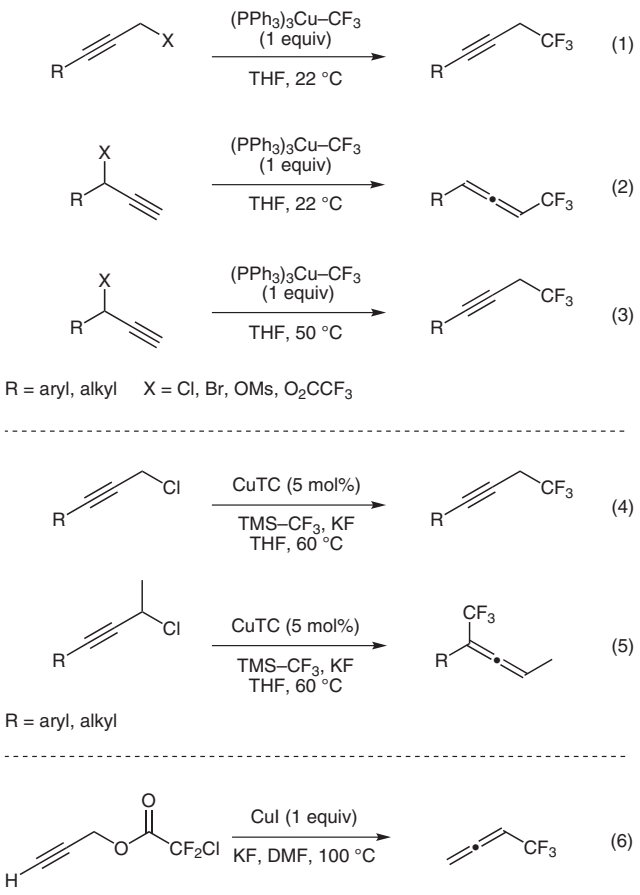
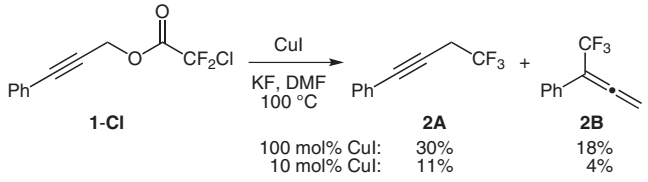


Scheme 2 Methods for the conversion of propargyl electrophiles into trifluoromethanes

metric copper(I) iodide encourages the development of a catalytic process.

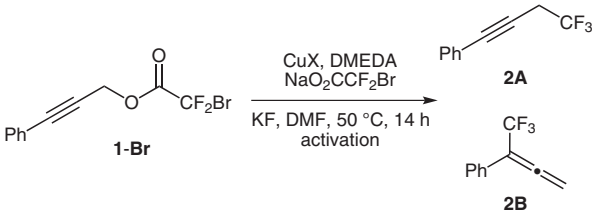
In order to establish whether this strategy could be expanded more generally to substituted propargyl substrates, we subjected 3-phenylpropynyl chlorodifluoroacetate (**1-Cl**) to the previously reported conditions utilizing stoichiometric copper(I) iodide.[14] Interestingly, this reaction provided a 1.7:1 mixture of propargyl (**2A**) and allenyl (**2B**) products (Scheme 3). With the goal of developing a catalytic variant of the reaction, subjecting **1-Cl** to similar conditions with 10 mol% of copper(I) iodide provided a low yield of trifluoromethylated product (Scheme 3).



Scheme 3 Decarboxylative trifluoromethylation provides a mixture of products

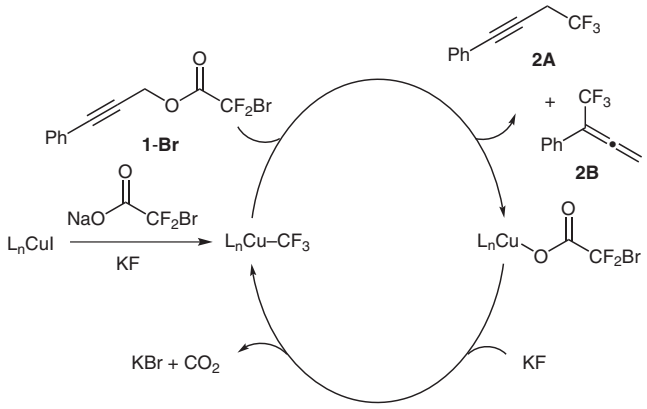
Given the poor reactivity of chlorodifluoroacetates compared to bromodifluoroacetates,[7a,14] the reaction of 3-phenylpropynyl bromodifluoroacetate (**1-Br**) was explored. Promotion of the reaction with stoichiometric copper provided a 57% yield of the trifluoromethylated product with 2.6:1 regioselectivity (Table 1, entry 1). In contrast, catalytic turnover was realized using just 10 mol% of copper(I) iodide, providing the trifluoromethylated product in 65% yield (Table 1, entry 2). Based on previous work in our laboratory,[7a] we hypothesized that the addition of *N*,*N*′-dimethylethylenediamine (DMEDA), and the use of an activation procedure might improve the yield of product. While the use of DMEDA alone was detrimental to the reaction (Table 1, entry 3), possibly because of the uncatalyzed reaction of the amine with the substrate, the employment of DMEDA, sodium bromo(difluoro)acetate (NaO_2CCF_2Br) and an activation procedure[7a] provided a 75% yield of the trifluoromethane-containing product and a 2.7:1 ratio of **2A**:**2B** (Table 1, entry 4). Heating copper(I) iodide, DMEDA, potassium fluoride and NaO_2CCF_2Br in *N*,*N*-dimethylformamide at 50 °C for 10 minutes prior to the addition of substrate may facilitate the formation of an active (DMEDA)Cu–CF_3 species (Scheme 4), and circumvent an induction period during which the substrate could be destroyed via nonproductive pathways.

Table 1 Catalytic Decarboxylative Trifluoromethylation Improved by DMEDA and an Activation Procedure[a]



Entry	CuX (mol%)	DMEDA (mol%)	Activation[b]	Yield (%)[c] (**A**:**B**)[d]
1[e]	I (100)	0	–	57 (2.6:1)
2	I (10)	0	–	65 (3.3:1)
3	I (10)	10	–	51 (3.6:1)
4	I (10)	10	yes	75 (2.7:1)
5	TC (10)	10	yes	52 (2.7:1)
6[f,g]	TC (5)	0	–	<5 (ND)
7[f,h]	TC (5)	0	–	0 (–)

[a] Reactions were performed with **1-Br** (0.20 mmol) and KF (0.40 mmol) in DMF (0.20 mL).
[b] Activation involved heating CuI, DMEDA, NaO_2CCF_2Br and KF in DMF for 10 minutes prior to injection of **1-Br**.
[c] Combined yield of **2A** and **2B** as determined by ^{19}F NMR spectroscopic analysis, using α,α,α-trifluorotoluene as an internal standard.
[d] Determined by ^{19}F NMR spectroscopic analysis. ND = not determined.
[e] DMF (0.60 mL).
[f] KF (0.30 mmol), THF (1.2 mL), 20 h.
[g] $TMSCF_3$ (0.30 mmol) was added to the reaction.
[h] 75% of **1-Br** remained, as determined by ^{19}F NMR spectroscopic analysis.

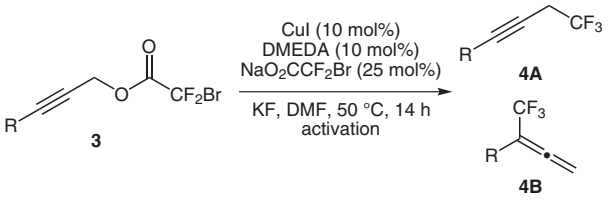


Scheme 4 Activation provides access into the proposed catalytic cycle

Attempted optimization of several other parameters did not lead to an improvement in the yield or selectivity. A broad screen of N- and O-based ligands did not result in increased yields or selectivity for the formation of **2A**. The regioselectivity of the reaction was not influenced dramatically by temperature, and isomerization was not observed upon prolonged heating. Incomplete conversion of the starting material was observed at 8–10-hour time points, therefore, an extended reaction time of 14 hours was selected for the general reaction conditions. In addition, various control reactions were conducted to probe the use of copper(I) thiophene-2-carboxylate as a catalyst for the present reaction. This salt has been employed for the regioselective conversion of propargyl chlorides into propargyl trifluoromethanes.[13] Treatment of **1-Br** with copper(I) thiophene-2-carboxylate provided a decreased yield (52%) and a similar regiochemical outcome (2.7:1) (Table 1, entry 5). Further, subjection of **1-Br** to the exact conditions that facilitated the conversion of propargyl chlorides into trifluoromethanes [$TMSCF_3$ (1.5 equiv) and KF (1.5 equiv) in THF at 60 °C for 20 h] formed less than 5% of the desired material, which demonstrates that there are inherent differences in the reactivity of propargyl chlorides and bromodifluoroacetates (Table 1, entry 6). When the reaction was conducted in the absence of $TMSCF_3$, only 25% conversion of **1** occurred, which suggests that decarboxylation does not occur under these conditions (Table 1, entry 7). Based on the results in entries 5–7, we hypothesize that selection of an appropriate solvent is critical for the present reaction.

The copper(I) iodide/DMEDA-catalyzed trifluoromethylation of propargyl bromodifluoroacetates **3** tolerates many useful and important functional groups. Electron-donating aryl ethers provided trifluoromethane-containing products in moderate yields (Table 2, entries 1 and 2). A variety of carbonyl-containing functional groups were compatible with the reaction conditions, including: esters, ketones, carbamates, and trifluoroacetamides (Table 2, entries 3–6). In addition, the successful reaction of the trifluoroacetamide gave the desired product, albeit in low yield, which provides additional evidence that Cu–CF_3 species tolerate protic functional groups (Table 2, entry 6).[9] The present trifluoromethylation reaction was conducted on an increased scale (7 mmol), and provided a typical yield according to ^{19}F NMR spectroscopy (Table 2, entry 9). In addition to aromatic substrates, an aliphatic substrate also afforded a trifluoromethylated product in moderate yield, and displayed distinct regioselectivity compared to the aromatic substrates (Table 2, entry 10). Based on the similarity of propargyl bromodifluoroacetates and cinnamyl bromodifluoroacetates, and the identical catalyst systems employed for decarboxylative trifluoromethylation, it is anticipated that other functional groups, including aryl bromides and triflates, thiophenes, anilines, and phthalimides should also be tolerated under the present reaction conditions.[7a] While attempts were made to separate regioisomeric products, we were unable to achieve sufficient separation via standard silica gel chromatography to enable practical isolation of pure products.

Table 2 Copper(I) Iodide/DMEDA-Catalyzed Reactions Tolerating Important Functional Groups[a]



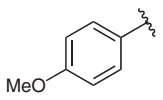
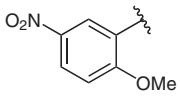
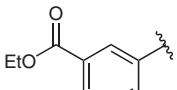
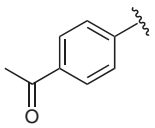
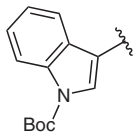
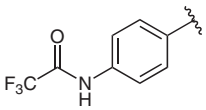
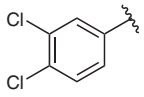
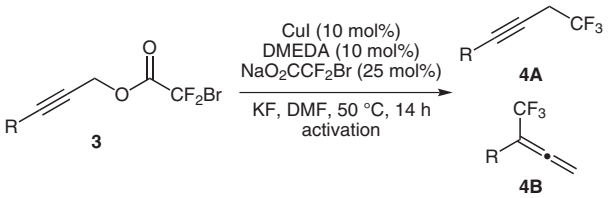
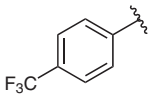
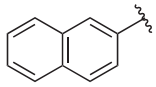
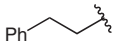
Entry	Product	Yield (%)[b]	**A**:**B**[c]
1		72 (77)	4.0:1 (3.5:1)
2		70 (78)	2.1:1 (2.3:1)
3		78 (83)	2.3:1 (2.6:1)
4		66 (70)	2.6:1 (2.9:1)
5		59 (62)	3.0:1 (2.9:1)
6		40 (44)	6.3:1 (3.4:1)
7		79 (84)	2.2:1 (2.5:1)

Table 2 Copper(I) Iodide/DMEDA-Catalyzed Reactions Tolerating Important Functional Groups[a] (continued)



Entry	Product	Yield (%)[b]	A:B[c]
8		70 (73)	1.7:1 (1.8:1)
9[d]		57 (77)	3.8:1 (2.2:1)
10		70 (69)	1:2.1 (1:1.6)

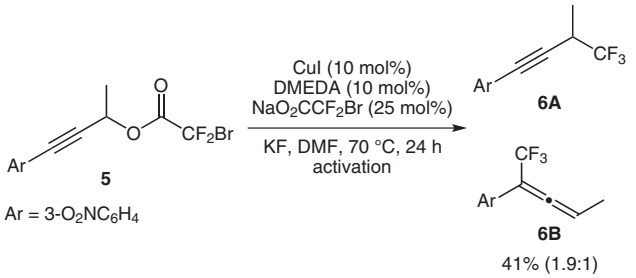
[a] Reactions were performed with substrates **3** (0.20 mmol), CuI (0.020 mmol), DMEDA (0.020 mmol), NaO_2CCF_2Br (0.050 mmol) and KF (0.40 mmol) in DMF (0.20 mL) at 50 °C for 14 h following a 10-minute activation period.

[b] Isolated yield of a purified mixture of regioisomers **4A** and **4B**; the figure in parentheses represents the combined yield of **4A** and **4B** as determined by ^{19}F NMR spectroscopic analysis, using α,α,α-trifluorotoluene as an internal standard.

[c] Ratio of regioisomers in the isolated material as determined by ^{1}H NMR spectroscopic analysis; the ratio in parentheses represents the ratio of isomers in the crude reaction mixture as determined by ^{19}F NMR spectroscopic analysis.

[d] Reaction conducted on a 7 mmol scale.

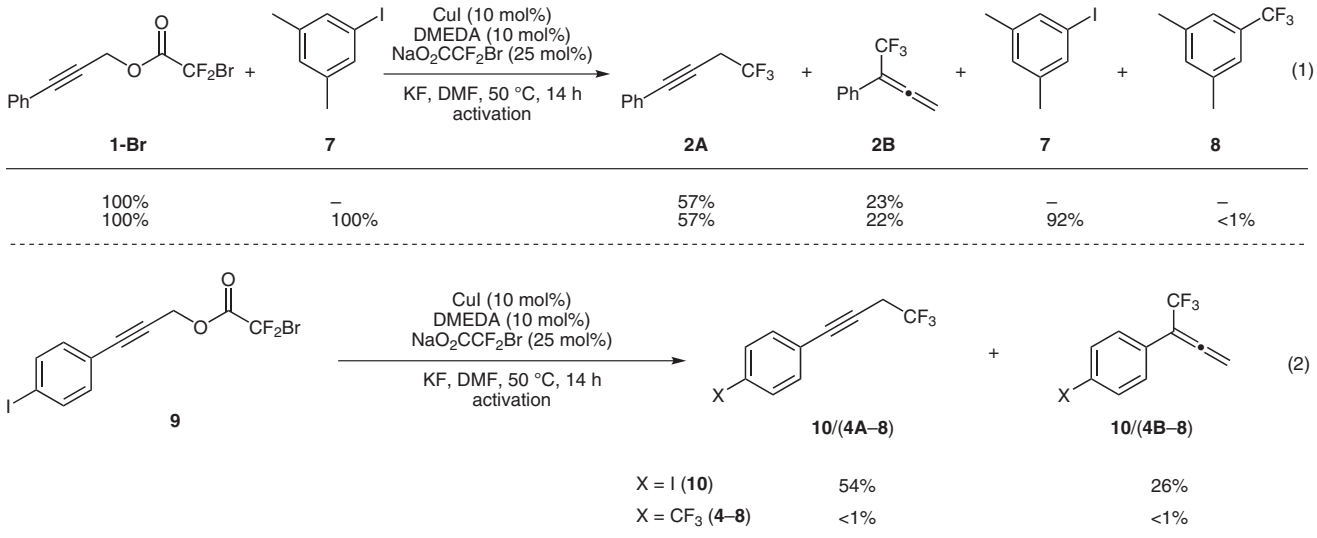
Using the standard reaction conditions, a secondary propargyl substrate was less reactive than primary substrates, and provided a 16% yield of the trifluoromethylated product after 12 hours at 50 °C. However, under more forcing conditions (70 °C, 24 h), both propargyl trifluoromethane **6A** and trifluoromethyl allene **6B** were



Scheme 5 Copper-catalyzed decarboxylative trifluoromethylation of secondary propargyl bromodifluoroacetates displays atypical reactivity. The ratio of products represents an average of multiple runs

formed (Scheme 5). For the reactions of propargyl bromodifluoroacetates, both primary and secondary substrates provided similar regiochemical outcomes, and propargylic trifluoromethanes were observed as the major product (Scheme 5). In contrast, previous copper-catalyzed trifluoromethylation reactions of propargyl electrophiles displayed substrate-dependent regioselectivity, with primary electrophiles providing propargyl trifluoromethanes, and secondary electrophiles yielding trifluoromethyl allenes (Scheme 2, eq 4 and 5).[13]

The present copper/DMEDA-based catalyst system demonstrated unique chemoselectivity compared to other copper-based catalyst systems. Several Cu–CF_3 complexes commonly react with aryl iodides under mild reaction conditions to furnish trifluoromethylarenes.[5,15] In order to determine whether propargylic trifluoromethylation could be achieved selectively in the presence of aryl iodides, an exogenous aryl iodide was added to a standard decarboxylative trifluoromethylation reaction.[16] The addition of one equivalent of aryl iodide **7** had no effect on the yield or selectivity of the reaction (Scheme 6, eq 1). GC analysis of the reaction revealed that 92% of the aryl iodide remained unconsumed. In addition, less than 1% of trifluoromethylarene **8** was observed, which demonstrates



Scheme 6 Propargylic trifluoromethylation is accomplished selectively in the presence of aryl iodides

the unique reactivity of this system. In order to confirm that substrates containing aryl iodides were compatible with the reaction conditions, 4-iodophenylpropynyl bromodifluoroacetate (**9**) was subjected to decarboxylative trifluoromethylation. As expected, a good combined yield (80%) of trifluoromethylated products **10A** and **10B** was obtained with typical regioselectivity (2.1:1, Scheme 6, eq 2). Again, only trace amounts of aromatic trifluoromethyl products **4A**-**8** and **4B**-**8** (see Table 2, entry 8) were observed.

In conclusion, a two-step, copper-catalyzed protocol enables the conversion of propargyl bromodifluoroacetic esters into a mixture of propargyl trifluoromethanes and trifluoromethyl allenes. This decarboxylative strategy utilizes the combination of bromo(difluoro)acetate and potassium fluoride as an attractive system for trifluoromethylation that produces carbon dioxide as a benign, easily separable by-product. For the copper-catalyzed trifluoromethylation, the use of DMEDA as a ligand, and an activation procedure, helped establish the catalyst system. Ongoing work in our laboratory aims to develop more selective and efficient catalyst systems for the current trifluoromethylation reaction, as well as other related fluoroalkylation reactions.

Unless otherwise noted, chemicals were purchased from commercial sources and used without further purification. Potassium fluoride (spray-dried) was ground into a fine powder with a mortar and pestle and dried in a vacuum oven (180 °C) for a minimum of 24 h prior to use. Dry solvents were used directly from a solvent purification system, in which the solvent was dried by passage through two columns of activated alumina under argon, or were purchased from commercial sources in Sure-Seal® bottles. All reactions were conducted under an atmosphere of dry N_2 using oven-dried glassware. Trifluoromethylation reactions were performed in resealable 15 mL test tubes sealed with PTFE septa, and all other reactions were performed in round-bottomed flasks sealed with rubber septa. Reactions were monitored by thin-layer chromatography using Analtech UNIPLATE™ Silica Gel HLF 250 micron glass plates precoated with 230–400 mesh silica impregnated with a fluorescent indicator (250 nm), visualizing with fluorescence quenching or *p*-anisaldehyde solution. Flash column chromatography was performed using a CombiFlash® RF–4x purification system. Silica gel was purchased from Sorbent Technologies (cat. #30930M-25, 60 Å, 40–63 μm). Yields of products reported in the experimental section refer to the isolated yield of a single experiment. ^{19}F NMR yields reported in tables were determined using α,α,α-trifluorotoluene (TFT) as an internal standard, and represent the average of at least two independent runs. Uncorrected melting points were measured on a Thomas Hoover Capillary Melting Point apparatus. Infrared spectra were recorded using a Shimadzu FTIR-8400S Fourier Transform Infrared Spectrometer. ^1H NMR spectra were recorded on a Bruker 400 Avance spectrometer (400 MHz) or a Bruker 500 Avance spectrometer (500 MHz). ^{13}C NMR spectra were recorded on a Bruker 500 Avance spectrometer (126 MHz). ^{19}F NMR spectra were recorded on a Bruker 400 Avance spectrometer (376 MHz). Chemical shifts (δ) for protons are reported in parts per million (ppm) downfield from tetramethylsilane, and are referenced to the proton resonance of residual $CHCl_3$ in the NMR solvent (δ = 7.27 ppm). Chemical shifts for carbon are reported in parts per million downfield from tetramethylsilane, and are referenced to the carbon resonances of the solvent peak (δ = 77.16 ppm). Chemical shifts for fluorine are reported in parts per millions, and are referenced to α,α,α-trifluorotoluene (δ = –63.72 ppm). Low-resolution mass spectra were recorded on a Shimatzu GCMS-QP2010 SE mass spectrometer. High-resolution mass spectra were recorded on a Waters LCT Premier™ mass spectrometer in the ESI mode.

Propargyl Alcohols; Representative Procedure

An oven-dried 25 mL round-bottomed flask was charged with CuI (76 mg, 0.40 mmol) and $Pd(PPh_3)_2Cl_2$ (0.14 g, 0.20 mmol). The flask was sealed and then evacuated and backfilled with N_2 three times. MeCN (0.010 L) and 4-iodoanisole (2.3 g, 0.010 mol) were injected, and the suspension cooled to –10 °C. Et_3N (6.3 mL, 45 mmol) was added dropwise, and the mixture was stirred for 10 min. Propargyl alcohol (0.64 mL, 11 mmol) was injected dropwise, and then the mixture was allowed to warm to 23 °C. After 4 h, the solvent was removed in vacuo, and the crude mixture was dissolved in EtOAc (60 mL). The solution was passed through a pad of silica, which was washed with additional EtOAc (3 × 30 mL). Further chromatographic purification (hexanes–EtOAc, 1:0→ 4:1) afforded 3-(4-methoxyphenyl)prop-2-yn-1-ol as a pale yellow solid (1.56 g, 96%).

Mp 69–70 °C (Lit.[17] 74–75 °C).

^1H NMR (400 MHz, $CDCl_3$): δ = 7.42–7.35 (m, 2 H), 6.89–6.81 (m, 2 H), 4.49 (d, *J* = 6.1 Hz, 2 H), 3.82 (s, 3 H), 1.64 (t, *J* = 6.1 Hz, 1 H).

Propargyl Bromodifluoroacetates; Representative Procedure

An oven-dried, single-neck round-bottomed flask (flask 1) was charged with bromodifluoroacetic acid (0.74 g, 4.2 mmol), and the system was attached to an N_2 bubbler. CH_2Cl_2 (0.010 L) and DMF (0.070 mL, 0.90 mmol) were injected, and then oxalyl chloride (0.33 mL, 3.9 mmol) was added dropwise. In a separate oven-dried, two-neck round-bottomed flask (flask 2), 3-(4-methoxyphenyl)prop-2-yn-1-ol (0.49 g, 3.0 mmol), Et_3N (0.84 mL, 6.0 mmol) and CH_2Cl_2 (0.010 L) were combined, and the system was attached to an N_2 bubbler via a glass adapter. This solution was cooled to 0 °C, and then the solution in flask 1 was transferred into flask 2 via cannula. The mixture was allowed to warm to 23 °C and stirred for 3 h. The mixture was diluted with CH_2Cl_2 (30 mL) and washed with 1 M HCl (25 mL), H_2O (25 mL), and brine (25 mL). The organic solution was dried over anhydrous Na_2SO_4, filtered and the solvent removed in vacuo. Chromatographic purification (hexanes–EtOAc, 19:1) afforded 3-(4-methoxyphenyl)prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate as a colorless oil (540 mg, 56%).

IR (film): 3010, 2839, 1780, 1606, 1510, 1290, 1249, 1172, 1120, 1031, 946, 833, 709, 603 cm^{-1}.

^1H NMR (400 MHz, $CDCl_3$): δ = 7.47–7.38 (m, 2 H), 6.91–6.79 (m, 2 H), 5.16 (s, 2 H), 3.83 (s, 3 H).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 160.4, 159.2 (t, *J* = 31.9 Hz), 133.7, 114.1, 113.5, 108.6 (t, *J* = 314.4 Hz), 88.9, 79.1, 56.8, 55.4.

^{19}F NMR (376 MHz, $CDCl_3$): δ = –62.30 (s, 2 F).

HRMS (EI): *m*/*z* $[M]^+$ calcd for $C_{12}H_9BrF_2O_3$: 317.9703; found: 317.9700.

Trifluoromethane-Containing Compounds; General Procedure

KF (23 mg, 0.40 mmol) was added to a resealable 15 mL test tube and dried in a vacuum oven for a minimum of 24 h. The test tube was removed from the oven, sealed with a PTFE septum, and cooled under N_2. CuI (3.8 mg, 0.020 mmol) and NaO_2CCF_2Br (9.8 mg, 0.050 mmol) were added, and the test tube was evacuated and backfilled with N_2 three times. DMEDA (2.2 μL, 0.020 mmol) and DMF (0.20 mL) were injected into the test tube, which was placed into an oil bath at 50 °C. The mixture was heated for 10 min, during which bubbling was observed and the solution changed from teal/blue to yellow. Next, propargyl bromodifluoroacetate (0.20 mmol) was injected into the test tube, and heating was maintained for 14 h. The mixture was diluted with EtOAc (3 mL), and TFT (24.6 μL, 0.200 mmol) was added as an internal standard. An aliquot was removed and a ^{19}F NMR spectrum was obtained. The aliquot was recombined, and the mixture was diluted further with EtOAc (15 mL). The

organic solution was washed with aq NH_4Cl solution (10 mL) and brine (10 mL), dried over anhydrous Na_2SO_4, filtered, and the solvent was removed in vacuo. Chromatographic purification afforded a mixture of propargyl trifluoromethane (**A**) and trifluoromethyl allene (**B**). The ratio of regioisomers was determined by ^{1}H NMR spectroscopy (propargylic CH_2/terminal CH_2 of allene). Note: the following numbering system is used for compounds **4**: **4A/B-x**, where x is an integer referring to the specific entry in Table 2.

Compounds 4A/B-1[13,18]

The general procedure was followed using 3-(4-methoxyphenyl)prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate (64 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes–EtOAc, 1:0→49:1) afforded a mixture of regioisomers as a yellow oil (31 mg, 72%). Analysis of the ^{1}H NMR spectrum revealed a 4.0:1 ratio of **A**/**B**.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.43–7.34 (m, 4 H, **A**/**B**), 6.94–6.89 (m, 2 H, **B**), 6.88–6.82 (m, 2 H, **A**), 5.51 (q, *J* = 3.4 Hz, 2 H, **B**), 3.83 (s, 3 H, **B**), 3.82 (s, 3 H, **A**), 3.26 (q, *J* = 9.6 Hz, 2 H, **A**).

^{19}F NMR (376 MHz, EtOAc): δ = –61.76 (t, *J* = 3.6 Hz, 3 F, **B**), –67.76 (t, *J* = 10.0 Hz, 3 F, **A**).

Compounds 4A/B-2

The general procedure was followed using 3-(2-methoxy-5-nitrophenyl)prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate (73 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes–EtOAc, 1:0→3:1) afforded a mixture of regioisomers as a colorless solid (36 mg, 70%). Analysis of the ^{1}H NMR spectrum revealed a 2.1:1 ratio of **A**/**B**.

Mp 76–81 °C.

IR (film): 3119, 3094, 2947, 2920, 2847, 1983, 1610, 1580, 1514, 1493, 1492, 1439, 1418, 1344, 1275, 1246, 1190, 1148, 1103, 1018, 968, 906, 891, 868, 833, 797, 750, 735, 694, 665, 638 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.31 (d, *J* = 2.8 Hz, 1 H, **A**), 8.28 (dd, *J* = 9.1, 2.8 Hz, 1 H, **B**), 8.24–8.20 (m, 2 H, **A**/**B**), 7.01 (d, *J* = 9.1 Hz, 1 H, **B**), 6.96 (d, *J* = 9.2 Hz, 1 H, **A**), 5.42 (q, *J* = 3.4 Hz, 2 H, **B**), 4.00 (s, 3 H, **A**), 3.96 (s, 3 H, **B**), 3.35 (q, *J* = 9.5 Hz, 2 H, **A**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 209.41 (q, *J* = 3.7 Hz, **B**), 164.97 (**A**), 162.43 (**B**), 141.23 (**B**), 141.09 (**A**), 129.59 (**A**), 126.67 (**B**), 126.51 (**B**), 126.21 (**A**), 124.10 (q, *J* = 277.0 Hz, **A**), 122.87 (q, *J* = 273.9 Hz, **B**), 119.90 (**B**), 112.56 (**A**), 110.98 (**B**), 110.48 (**A**), 95.74 (q, *J* = 37.2 Hz, **B**), 83.93 (q, *J* = 5.0 Hz, **A**), 82.19 (**B**), 78.61 (**A**), 56.79 (**A**), 56.58 (**B**), 27.15 (q, *J* = 34.9 Hz, **A**).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –62.45 (t, *J* = 3.5 Hz, 3 F, **B**), –67.35 (t, *J* = 9.9 Hz, 3 F, **A**).

MS (CI): *m*/*z* $[M]^+$ calcd for $C_{11}H_8F_3NO_3$: 259.0; found: 259.0.

Compounds 4A/B-3

The general procedure was followed using ethyl 3-[3-(2-bromo-2,2-difluoroacetoxy)prop-1-yn-1-yl]benzoate (72 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes–EtOAc, 1:0→49:1) afforded a mixture of regioisomers as a pale green oil (0.040 g, 78%). Analysis of the ^{1}H NMR spectrum revealed a 2.3:1 ratio of **A**/**B**.

IR (film): 3067, 2984, 2932, 2854, 1971, 1720, 1472, 1367, 1298, 1256, 1231, 1173, 1148, 1111, 1084, 1026, 908, 872, 754 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.16–8.09 (m, 2 H, **A**/**B**), 8.05–7.97 (m, 2 H, **A**/**B**), 7.66–7.60 (m, 2 H, **A**/**B**), 7.47 (t, *J* = 7.8 Hz, 1 H, **B**), 7.41 (t, *J* = 7.8 Hz, 1 H, **A**), 5.61 (q, *J* = 3.4 Hz, 2 H, **B**), 4.46–4.33 (m, 4 H, **A**/**B**), 3.30 (q, *J* = 9.5 Hz, 2H, **A**), 1.41 (t, *J* = 7.1 Hz, 6 H, **A**/**B**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 208.71 (q, *J* = 4.0 Hz, **B**), 166.23 (**B**), 165.92 (**A**), 136.02 (**A**), 133.06 (**A**), 131.27 (**B**), 131.26 (q, *J* = 1.3 Hz, **B**), 130.94 (**A**), 129.85 (**A**), 129.79 (**B**), 129.39 (**B**), 128.94 (**B**), 128.59 (**A**), 128.44 (**B**), 124.24 (q, *J* = 277.4 Hz, **A**), 123.28 (q, *J* = 273.9 Hz, **B**), 122.65 (**A**), 101.42 (q, *J* = 35.7 Hz, **B**), 84.23 (**B**), 83.56 (**A**), 78.59 (q, *J* = 5.1 Hz, **A**), 61.42 (**A**), 61.38 (**B**), 26.93 (q, *J* = 34.9 Hz, **A**), 14.46 (**A**/**B**).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –61.59 (t, *J* = 3.6 Hz, 3 F, **B**), –67.51 (t, *J* = 10.0 Hz, 3 F, **A**).

MS (CI): *m*/*z* $[M]^+$ calcd for $C_{13}H_{11}F_3O_2$: 256.1; found: 256.1.

Compounds 4A/B-4

The general procedure was followed using 3-(4-acetylphenyl)prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate (66 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes–EtOAc, 1:0→49:1) afforded a mixture of regioisomers as a yellow oil (0.030 g, 66%). Analysis of the ^{1}H NMR spectrum revealed a 2.6:1 ratio of **A**/**B**.

IR (film): 3067, 2964, 2932, 2854, 1969, 1933, 1686, 1603, 1558, 1418, 1404, 1362, 1306, 1263, 1178, 1150, 1109, 1016, 957, 935, 906, 833, 717, 679, 628, 592 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.99–7.94 (m, 2 H, **B**), 7.94–7.89 (m, 2 H, **A**), 7.57–7.52 (m, 4 H, **A**/**B**), 5.64 (q, *J* = 3.3 Hz, 2 H, **B**), 3.32 (q, *J* = 9.5 Hz, 2 H, **A**), 2.62 (s, 3 H, **B**), 2.61 (s, 3 H, **A**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 209.23 (q, *J* = 3.9 Hz, **B**), 197.50 (**B**), 197.42 (**A**), 136.80 (**A**), 136.60 (**B**), 134.07 (**B**), 132.15 (**A**), 129.99 (**A**), 128.85 (**B**), 128.35 (**A**), 127.17 (q, *J* = 1.3 Hz, **B**), 127.08 (**A**), 124.13 (q, *J* = 277.4 Hz, **A**), 123.17 (q, *J* = 273.9 Hz, **B**), 101.72 (**B**), 84.45 (**B**), 83.74 (**A**), 80.99 (q, *J* = 5.1 Hz, **A**), 27.03 (q, *J* = 35.0 Hz, **A**), 26.81 (**A**), 26.78 (**B**).

^{19}F NMR (376 MHz, EtOAc): δ = –63.30 to –63.53 (m, 3 F, **B**), –67.66 (t, *J* = 10.0 Hz, 3 F, **A**).

MS (CI): *m*/*z* $[M]^+$ calcd for $C_{12}H_9F_3O$: 226.1; found: 226.1.

Compounds 4A/B-5

The general procedure was followed using *tert*-butyl 3-[3-(2-bromo-2,2-difluoroacetoxy)prop-1-yn-1-yl]-1*H*-indole-1-carboxylate (86 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes–EtOAc, 1:0→9:1) afforded a mixture of regioisomers as a viscous orange oil (38 mg, 59%). Analysis of the ^{1}H NMR spectrum revealed a 3.0:1 ratio of **A**/**B**.

IR (film): 3159, 3055, 2980, 2932, 2851, 1740, 1558, 1475, 1454, 1420, 1375, 1357, 1308, 1279, 1234, 1256, 1234, 1111, 1049, 1032, 854, 831, 746, 729 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.19 (d, *J* = 8.5 Hz, 1 H, **B**), 8.15 (d, *J* = 8.2 Hz, 1 H, **A**), 7.87 (dt, *J* = 8.0, 1.0 Hz, 1 H, **B**), 7.79 (s, 1 H, **A**), 7.73 (s, 1 H, **B**), 7.68–7.60 (m, 1 H, **A**), 7.37 (td, *J* = 7.8, 1.4 Hz, 2 H, **A**/**B**), 7.31 (td, *J* = 7.5, 1.1 Hz, 1 H, **A**), 7.29–7.24 (m, 1 H, **B**), 5.69 (qd, *J* = 3.0, 0.9 Hz, 2 H, **B**), 3.37 (q, *J* = 9.6 Hz, 2 H, **A**), 1.70 (s, 9 H, **B**), 1.68 (s, 9 H, **A**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 208.94 (q, *J* = 3.7 Hz, **B**), 149.49 (**B**), 149.12 (**A**), 135.48 (**B**), 134.66 (**A**), 130.53 (**A**), 129.57 (**A**), 128.40 (**B**), 125.40 (**A**), 125.17 (**B**), 124.35 (q, *J* = 277.1 Hz, **A**), 124.21 (q, *J* = 1.3 Hz, **B**), 123.41 (**A**), 123.33 (q, *J* = 273.7 Hz, **B**), 123.07 (**B**), 120.07 (**A**), 119.93 (**B**), 115.46 (**B**), 115.40 (**A**), 107.96 (**B**), 102.44 (**A**), 95.70 (q, *J* = 36.1 Hz, **B**), 84.59 (**A**), 84.58 (**A**), 84.52 (**B**), 81.08 (q, *J* = 5.1 Hz, **A**), 76.64 (**B**), 28.30 (**B**), 28.28 (**A**), 27.20 (q, *J* = 34.8 Hz, **A**).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –63.41 (t, *J* = 3.5 Hz, 3 F, **B**), –67.66 (t, *J* = 9.9 Hz, 3 F, **A**).

HRMS (ESI): *m*/*z* [2 M + Na]$^+$ calcd for $C_{34}H_{32}F_6N_2O_4Na$: 669.2164; found: 669.2179 (2.2 ppm).

Compounds 4A/B-6

The general procedure was followed using 3-[4-(2,2,2-trifluoroacetamido)phenyl]prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate (80 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes–CH_2Cl_2, 1:0→1:1) afforded a mixture of regioisomers as a colorless solid (24 mg, 40%). Analysis of the ^{1}H NMR spectrum revealed a 6.3:1 ratio of **A**/**B**.

IR (film): 3300, 3202, 3136, 2964, 1705, 1607, 1547, 1512, 1410, 1366, 1281, 1246, 1202, 1155, 1107, 959, 906, 839, 727, 704, 654 cm^{-1}.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.89 (s, 1 H, **A**), 7.83 (s, 1 H, **B**), 7.62–7.58 (m, 2 H, **B**), 7.58–7.54 (m, 2 H, **A**), 7.52–7.45 (m, 4 H, **A**/**B**), 5.60 (q, *J* = 3.4 Hz, 2 H, **B**), 3.29 (q, *J* = 9.5 Hz, 2 H, **A**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 208.65 (q, *J* = 4.4 Hz, **B**), 154.89 (q, *J* = 37.5 Hz, **B**), 154.80 (q, *J* = 37.5 Hz, **A**), 135.38 (**A**), 135.00 (**B**), 133.10 (**A**), 128.16 (q, *J* = 1.5 Hz, **B**), 124.25 (q, *J* = 276.9 Hz, **A**), 123.29 (q, *J* = 275.6 Hz, **B**), 120.71 (**A**), 120.32 (**B**), 120.25 (**A**), 120.18 (**B**), 115.70 (q, *J* = 288.8 Hz, **B**), 115.69 (q, *J* = 288.8 Hz, **A**), 101.24 (q, *J* = 35.4 Hz, **B**), 84.25 (**B**), 83.51 (**A**), 78.48 (q, *J* = 5.0 Hz, **A**), 26.94 (q, *J* = 34.8 Hz, **A**).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –61.55 (t, *J* = 3.0 Hz, 3 F, **B**), –67.35 (t, *J* = 9.5 Hz, 6 F, **A**), –76.69 (3 F, **A**/**B**).

MS (CI): *m*/*z* [M]$^+$ calcd for $C_{12}H_7F_6NO$: 295.0; found: 295.0.

Compounds 4A/B-7

The general procedure was followed using 3-(3,4-dichlorophenyl)prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate (72 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes) afforded a mixture of regioisomers as a pale yellow oil (0.040 g, 79%). Analysis of the ^{1}H NMR spectrum revealed a 2.2:1 ratio of **A**/**B**.

IR (film): 3074, 2928, 1973, 1533, 1475, 1466, 1364, 1352, 1281, 1254, 1178, 1151, 1130, 1111, 1034, 906, 881, 822 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.55 (d, *J* = 2.0 Hz, 1 H, **A**), 7.52 (d, *J* = 2.2 Hz, 1 H, **B**), 7.45 (d, *J* = 8.5 Hz, 1 H, **B**), 7.40 (d, *J* = 8.3 Hz, 1 H, **A**), 7.30–7.26 (m, 2 H, **A**/**B**), 5.63 (q, *J* = 3.3 Hz, 2 H, **B**), 3.28 (q, *J* = 9.5 Hz, 2 H, **A**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 208.60 (q, *J* = 3.9 Hz, **B**), 133.64 (**A**), 133.41 (**A**), 133.16 (**B**), 132.75 (**A**), 132.58 (**B**), 131.10 (**A**), 130.80 (**B**), 130.54 (**A**), 129.38 (**B**), 129.03 (q, *J* = 1.7 Hz, **B**), 126.30 (q, *J* = 1.7 Hz, **B**), 124.12 (q, *J* = 276.9 Hz, **A**), 123.02 (q, *J* = 273.1 Hz, **B**), 122.18 (**A**), 100.59 (q, *J* = 35.2 Hz, **B**), 84.69 (**B**), 82.28 (**A**), 79.80 (q, *J* = 5.1 Hz, **A**), 26.92 (q, *J* = 34.9 Hz, **A**).

^{19}F NMR (376 MHz, EtOAc): δ = –61.59 (t, *J* = 3.6 Hz, 3 F, **B**), –67.51 (t, *J* = 10.0 Hz, 3 F, **A**).

HRMS (ES): *m*/*z* [M]$^+$ calcd for $C_{10}H_5Cl_2F_3$: 251.9720; found: 251.9721 (0.3 ppm).

Compounds 4A/B-8

The general procedure was followed using 3-[4-(trifluoromethyl)phenyl]prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate (71 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes–EtOAc, 1:0→49:1) afforded a mixture of regioisomers as a colorless oil (35 mg, 70%). Analysis of the ^{1}H NMR spectrum revealed a 1.7:1 ratio of **A**/**B**.

IR (film): 3063, 2934, 1971, 1927, 1618, 1406, 1366, 1329, 1281, 1267, 1151, 1130, 1105, 1068, 1018, 937, 906, 870, 843, 735, 723 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.67–7.53 (m, 8 H, **A**/**B**), 5.64 (q, *J* = 3.4 Hz, 2 H, **B**), 3.31 (q, *J* = 9.5 Hz, 2 H, **A**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 209.04 (q, *J* = 4.1 Hz, **B**), 133.10 (q, *J* = 1.6 Hz, **B**), 132.27 (**A**), 130.64 (q, *J* = 32.7 Hz, **A**), 130.36 (q, *J* = 32.7 Hz, **B**), 127.41 (q, *J* = 1.6 Hz, **B**), 126.06 (q, *J* = 1.7 Hz, **A**), 125.82 (q, *J* = 3.8 Hz, **B**), 125.42 (q, *J* = 3.9 Hz, **A**), 124.15 (q, *J* = 278.6 Hz, **A**), 124.02 (q, *J* = 272.2 Hz, **B**), 123.93 (q, *J* = 271.8 Hz, **A**), 123.13 (q, *J* = 274.8 Hz, **B**), 101.33 (q, *J* = 35.0 Hz, **B**), 84.47 (**B**), 83.21 (**A**), 80.23 (q, *J* = 5.1 Hz, **A**), 26.96 (q, *J* = 34.9 Hz, **A**).

^{19}F NMR (376 MHz, EtOAc): δ = –61.50 (t, *J* = 3.5 Hz, 3 F, **B**), –63.79 (3 F, **B**), –63.93 (3 F, **A**), –67.42 (t, *J* = 9.9 Hz, 3 F, **A**).

MS (CI): *m*/*z* [M]$^+$ calcd for $C_{11}H_6F_6$: 252.0; found: 252.0.

Compounds 4A/B-9[13,18]

The general procedure was followed using 3-(naphthalen-2-yl)prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate (2.4 g, 7.0 mmol), CuI (130 mg, 0.70 mmol), DMEDA (75 μL, 0.70 mmol), NaO_2CCF_2Br (0.35 g, 1.8 mmol), KF (0.81 g, 14 mmol), with DMF (7.0 mL) as solvent. Work-up and chromatographic purification (hexanes–EtOAc, 1:0→49:1) afforded a mixture of regioisomers as a pale yellow solid (0.93 g, 57%). Analysis of the ^{1}H NMR spectrum revealed a 3.8:1 ratio of **A**/**B**.

Mp 42–45 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.00 (s, 1 H, **A**), 7.93 (s, 1 H, **B**), 7.88–7.77 (m, 6 H, **A**/**B**), 7.57–7.47 (m, 6 H, **A**/**B**), 5.63 (q, *J* = 3.3 Hz, 2 H, **B**), 3.34 (q, *J* = 9.6 Hz, 2 H, **B**).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –61.30 (t, *J* = 3.6 Hz, 3 F, **B**), –67.56 (t, *J* = 10.1 Hz, 3 F, **A**).

Compounds 4A/B-10

The general procedure was followed using 5-phenylpent-2-yn-1-yl 2-bromo-2,2-difluoroacetate (63 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes) afforded a mixture of regioisomers as a tan oil (0.030 g, 70%). Analysis of the ^{1}H NMR spectrum revealed a 1:2.1 ratio of **A**/**B**.

IR (film): 3088, 3065, 3030, 2932, 2862, 1985, 1954, 1605, 1497, 1454, 1366, 1333, 1281, 1261, 1200, 1157, 1115, 1055, 980, 908, 864, 744, 700 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.37–7.28 (m, 4 H, **A**/**B**), 7.26–7.19 (m, 6 H, **A**/**B**), 5.18 (sext, *J* = 3.6 Hz, 2 H, **B**), 3.01 (qt, *J* = 9.7, 2.4 Hz, 2 H, **A**), 2.90–2.73 (m, 4 H, **A**/**B**), 2.54–2.41 (m, 4 H, **A**/**B**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 206.73 (q, *J* = 4.1 Hz, **B**), 140.80 (**B**), 140.54 (**A**), 128.59 (**A**/**B**), 128.56 (**B**), 128.52 (**A**), 126.48 (**A**), 126.35 (**B**), 124.53 (q, *J* = 277.8 Hz, **A**), 123.94 (q, *J* = 274.5 Hz, **B**), 98.11 (q, *J* = 34.0 Hz, **B**), 84.28 (**A**), 82.54 (**B**), 69.21 (q, *J* = 5.1 Hz, **A**), 34.94 (**A**), 33.64 (**B**), 27.70 (**B**), 26.28 (q, *J* = 34.6 Hz, **A**), 20.99 (**A**).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –61.60 (t, *J* = 3.7 Hz, 3 F, **B**), –67.54 (t, *J* = 10.0 Hz, 3 F, **A**).

MS (CI): *m*/*z* [M]$^+$ calcd for $C_{12}H_{11}F_3$: 212.1; found: 212.1.

Compounds 6A/B

The general procedure was followed using 4-(3-nitrophenyl)but-3-yn-2-yl 2-bromo-2,2-difluoroacetate (**5**) (70 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes–EtOAc, 1:0→9:1) afforded a mixture of regioisomers

as a yellow oil (0.020 g, 41%). Analysis of the ^{1}H NMR spectrum revealed a 1.6:1 ratio of **A**/**B** (single run).

IR (film): 3090, 2961, 2926, 2856, 1963, 1535, 1481, 1441, 1352, 1327, 1248, 1178, 1155, 1119, 980, 964, 926, 901, 806, 739, 710, 687 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.41–8.37 (m, 1 H, **A**), 8.32–8.24 (m, 2 H, **A**/**B**), 8.20–8.14 (m, 1 H, **B**), 7.85–7.80 (m, 1 H, **A**), 7.79–7.73 (m, 1 H, **B**), 7.63–7.53 (m, 2 H, **A**/**B**), 6.08 (qt, *J* = 7.5, 3.1 Hz, 1 H, **B**), 4.43 (qq, *J* = 7.8, 2.5 Hz, 1 H, **A**), 1.97–1.93 (m, 6 H, **A**/**B**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 205.60 (q, *J* = 3.9 Hz, **B**), 148.66 (**B**), 148.47 (**A**), 135.54 (**A**), 134.62 (**B**), 132.72 (q, *J* = 1.8 Hz, **B**), 129.79 (**B**), 129.74 (**A**), 124.62 (**A**), 124.61 (**B**), 124.09 (q, *J* = 280.4 Hz, **A**), 124.00 (**A**), 123.07 (q, *J* = 274.8 Hz, **B**), 122.85 (**A**), 122.19 (q, *J* = 1.8 Hz, **B**), 100.12 (q, *J* = 35.3 Hz, **B**), 96.56 (**B**), 83.59 (**A**), 70.34 (q, *J* = 3.4 Hz, **A**), 43.30 (q, *J* = 31.8 Hz, **A**), 13.37 (**B**), 3.79 (**A**).

^{19}F NMR (376 MHz, $CDCl_3$): δ = –61.70 (s, 3 F, **B**), –71.74 (d, *J* = 7.5 Hz, 3 F, **A**).

MS (CI): *m*/*z* $[M]^+$ calcd for $C_{11}H_8F_3NO_2$: 243.1; found: 243.1.

Compounds 10A/B

The general procedure was followed using 3-(4-iodophenyl)prop-2-yn-1-yl 2-bromo-2,2-difluoroacetate (**9**) (83 mg, 0.20 mmol), CuI (3.8 mg, 0.020 mmol), DMEDA (2.2 μL, 0.020 mmol), NaO_2CCF_2Br (9.8 mg, 0.050 mmol), KF (23 mg, 0.40 mmol), with DMF (0.20 mL) as solvent. Work-up and chromatographic purification (hexanes) afforded a mixture of regioisomers as an amorphous tan solid (0.050 g, 80%). Analysis of the ^{1}H NMR spectrum revealed a 2.0:1 ratio of **A**/**B**.

IR (film): 3065, 2978, 1961, 1541, 1485, 1391, 1366, 1319, 1279, 1263, 1254, 1173, 1148, 1111, 1061, 1007, 935, 906, 868, 820, 743, 665 cm^{-1}.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.73–7.69 (m, 2 H, **B**), 7.69–7.64 (m, 2 H, **A**), 7.21–7.15 (m, 4 H, **A**/**B**), 5.56 (q, *J* = 3.4 Hz, 2 H, **B**), 3.27 (q, *J* = 9.5 Hz, 2 H, **A**).

^{13}C NMR (126 MHz, $CDCl_3$): δ = 208.50 (q, *J* = 4.0 Hz, **B**), 138.00 (**B**), 137.66 (**A**), 133.47 (**A**/**B**), 128.87 (q, *J* = 1.5 Hz, **B**), 124.18 (q, *J* = 276.9 Hz, **A**), 123.19 (q, *J* = 273.6 Hz, **B**), 121.78 (**A**), 94.88 (**A**), 94.13 (**B**), 84.23 (**A**), 83.60 (**B**), 79.14 (q, *J* = 5.1 Hz, **A**), 26.99 (q, *J* = 34.9 Hz, **A**). Note: the terminal substituted carbon of allene **B** could not be distinguished from the baseline [expected to be a quartet (*J* ≈ 35 Hz) between δ = 102–100].

^{19}F NMR (376 MHz, EtOAc): δ = –61.60 (t, *J* = 3.7 Hz, 3 F, **B**), –67.54 (t, *J* = 10.0 Hz, 3 F, **A**).

MS (CI): *m*/*z* $[M]^+$ calcd for $C_{10}H_6F_3I$: 310.0; found: 310.0.

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