# Supporting Information 

# Reagent-Controlled Oxidative Aromatization in Iodocyclization: Switchable Access to Dihydropyrazoles and Pyrazoles 

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## Experimental Section

General. Melting point was measured by Yanagimoto micro melting point apparatus. IR spectra were measured on a Perkin Elmer FT-IR spectrometer, model Paragon 1000, using $\mathrm{CHCl}_{3} .{ }^{1} \mathrm{H}$ NMR and ${ }^{13} \mathrm{C}$ NMR spectra were determined on a Varian Gemini-300 or a Varian Mercury-300 or a Varian VXR-500 superconducting FT-NMR spectrometer in $\mathrm{CDCl}_{3}$ unless otherwise noted (tetramethylsilane as internal reference). $J$-Values are given in Hz . Mass spectra were taken on a Hitachi M-4100 spectrometer or a Thermo Fisher Scientific Exactive spectrometer. Column chromatography was performed using Kanto Silica Gel 60 N (spherical, neutral). All reaction was carried out under Ar atmosphere. All reagents were directly used as obtained commercially.

## Preparation of Propargylic Hydrazide 1:

Propargylic hydrazides 1a-j were prepared by Mitsunobu reaction of corresponding propargylic alcohols with DIAD and $\mathrm{Ph}_{3} \mathrm{P}(\mathbf{G P} 1) .{ }^{1}$ Propargylic hydrazides $\mathbf{1 k}$-I were prepared by the reaction of corresponding propargylic bromides with diisopropyl hydrazodicarboxylate (GP2). The observed peaks of products $\mathbf{1}$ in NMR were obscure due to the existence of rotamers. This tendency is common in this class of compounds. ${ }^{2}$ Due to extensive broadening of the peaks, peak listings are not fully provided for some compounds.

## General Procedure for the Preparation of Propargylic Hydrazides 1a-j by Mitsunobu Reaction (GP1)





To a solution of propargylic alcohols ( 1 equiv) and $\mathrm{Ph}_{3} \mathrm{P}$ (1.2-2.4 equiv) in dry THF ( 0.1 M ) at 0 ${ }^{\circ} \mathrm{C}$ was added DIAD (1.2-2.4 equiv) by portions and the reaction mixture was warmed to room temperature and stirred for overnight. After reaction completed, the mixture was evaporated in vacuo. The residue was purified by flash column chromatography on silica gel eluting with hexane/AcOEt to give 1.

Diisopropyl 1-(3-phenyl-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1a)
According to GP1, 1a ( $2.01 \mathrm{~g}, 79 \%$ ) was obtained from 3-phenyl-2-propyn-1-ol ( $1.06 \mathrm{~g}, 8.00 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}(5.04 \mathrm{~g}, 19.2 \mathrm{mmol}$ ), and DIAD ( $3.72 \mathrm{~mL}, 19.2 \mathrm{mmol}$ ). Eluent: hexane $/ \mathrm{AcOEt}=3 / 1$. Colorless oil; IR $v_{\max }: 3518$ (N-H), 3411 (N-H), 2986 (C-H), 1714 (C=O),


1a 1600 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.43-7.41$ (m, 2H), 7.31-7.27 (m, 3H), 6.76 (br s,
$5 / 7 \mathrm{H}$ ), 6.59 (br s, $2 / 7 \mathrm{H}$ ) 4.99 (sept, $J=6.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.55 (br s, 2 H ), 1.27 (d, $J=6.0 \mathrm{~Hz}, 12 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 155.3$ (2C), 131.7, 128.4, 128.2, 122.5, 84.1, 83.4, 70.6, 69.8, 40.3, 21.95, 21.89; HR-EIMS calcd for $\mathrm{C}_{17} \mathrm{H}_{22} \mathrm{~N}_{2} \mathrm{O}_{4}\left(\mathrm{M}^{+}\right)$318.1580. Found 318.1595.

## Diisopropyl 1-(3-(2-methoxyphenyl)-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1b)

According to GP1, 1b ( $616 \mathrm{mg}, 88 \%$ ) was obtained from 3-(2-methoxyphenyl)-2-propyn-1-ol ${ }^{3}$ ( $324 \mathrm{mg}, 2.00 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}$ (1.26 g, 4.80 mmol ), and DIAD ( $930 \mu \mathrm{~L}, 4.80 \mathrm{mmol}$ ). Eluent: hexane $/$ AcOEt $=3 / 1$.


Colorless oil; IR $v_{\text {max }} 3528$ (N-H), 3412 (N-H), 2986 (C-H), 1714
(C=O), 1598 (aryl); ${ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.39$ (dd, $J=7.5,1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.30 (dd, $J=7.5$, $1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 6.90 (td, $J=7.5,1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 6.87 (d, $J=9.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 6.82 (br s, 1H), 4.99 (sept, 6.5 $\mathrm{Hz}, 2 \mathrm{H}$ ), 4.59 (br s, 2H) 3.88 (s, 3H), 1.27 (d, $J=6.0 \mathrm{~Hz}, 12 \mathrm{H}$ ), ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ 160.1, 155.4 (2C), 133.6, 130.0, 120.4, 111.6, 110.6, 87.6, 80.8, 70.6, 69.8, 55.7, 41.4, 40.5, 22.04, 22.00; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{24} \mathrm{~N}_{2} \mathrm{O}_{5}\left(\mathrm{M}^{+}\right)$348.1685. Found 348.1691.

## Diisopropyl 1-(3-(3-methoxyphenyl)-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1c)

According to GP1, 1c ( $216 \mathrm{mg}, 18 \%$ ) was obtained from 3-(3-methoxyphenyl)-2-propyn-1-ol ${ }^{4}$ ( $554 \mathrm{mg}, 3.42 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}$ ( $1.07 \mathrm{~g}, 4.10 \mathrm{mmol}$ ), and DIAD ( $794 \mu \mathrm{~L}, 4.10 \mathrm{mmol}$ ). Eluent: hexane/AcOEt = 3/1.
Colorless oil; IR $v_{\max }$ : 3528 (N-H), 3411 (N-H), 2986 (C-H), 1717

(C=O), 1597 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.21(\mathrm{t}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.02(\mathrm{~d}, \mathrm{~J}=7.5$ $\mathrm{Hz}, 1 \mathrm{H}$ ), 6.95 (s, 1H), 6.88 (ddd, $J=7.5,2.5,0.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 6.66 (br s, $5 / 7 \mathrm{H}$ ), 6.44 (br s, 2/7H), 4.99 (sept, $6.5 \mathrm{~Hz}, 2 \mathrm{H}$ ), $4.54(\mathrm{br} \mathrm{s}, 2 \mathrm{H}) 3.80(\mathrm{~s}, 3 \mathrm{H}), 1.27(\mathrm{~d}, J=6.5 \mathrm{~Hz}, 12 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( 125 MHz , $\mathrm{CDCl}_{3}$ ) $\delta 159.2,155.3$ (2C), 129.4, 124.3, 123.5, 116.6, 115.1, 84.4, 83.3, 70.8, 70.0, 55.3, 40.3, 22.03, 21.97; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{24} \mathrm{~N}_{2} \mathrm{O}_{5}\left(\mathrm{M}^{+}\right)$348.1685. Found 348.1693.

## Diisopropyl 1-(3-(4-methoxyphenyl)-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1d)

According to GP1, 1d ( $454 \mathrm{mg}, 71 \%$ ) was obtained from 3-(4-methoxyphenyl)-2-propyn-1-ol ${ }^{3}$ ( $300 \mathrm{mg}, 1.85 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}(1.16 \mathrm{~g}, 4.44 \mathrm{mmol})$, and DIAD ( $860 \mu \mathrm{~L}, 4.44 \mathrm{mmol}$ ). Eluent: hexane $/ \mathrm{AcOEt}=7 / 3$.
Colorless oil; IR $v_{\max }$ : 3518 (N-H), 3421 (N-H), 2986 (C-H),


1d 1739 (C=O), 1607 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.36$ (dd, $J=6.9,2.1 \mathrm{~Hz}, 2 \mathrm{H}$ ), 6.83 (dd, $J=6.9,2.1 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.98 (sept, $J=6.3 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.53 (br s, 2H), 3.80 (s, 3H), 1.27 (d, $J=6.3$ $\mathrm{Hz}, 12 \mathrm{H})$; ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ 159.7, 155.4 (2C), 133.3, 114.7, 114.0, 84.1, 82.1, 70.7, 69.9, 55.3, 41.1, 40.4, 22.04, 22.00; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{24} \mathrm{~N}_{2} \mathrm{O}_{5}\left(\mathrm{M}^{+}\right)$348.1685. Found
348.1671.

Diisopropyl 1-(3-(4-nitrophenyl)-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1e)
According to GP1, 1e (262 mg, 43\%) was obtained from 3-(4-nitrophenyl)-2-propyn-1-ol ${ }^{5}$ ( $300 \mathrm{mg}, 1.69 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}$ ( $533 \mathrm{mg}, 2.03 \mathrm{mmol}$ ), and DIAD ( $394 \mu \mathrm{~L}, 2.03 \mathrm{mmol}$ ). Eluent: hexane/AcOEt = 3/1.
Yellow crystals; m.p. $78-91{ }^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}: 3500$


1e (N-H), 3410 (N-H), 2986 (C-H), 1717 (C=O), 1596 (aryl), $1520\left(\mathrm{NO}_{2}\right), 1343\left(\mathrm{NO}_{2}\right) \mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.18$ (d, $J=9.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 7.57 (d, $J=9.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 6.65 (br s, 4/5H), 6.45 (br s, $1 / 5 \mathrm{H}$ ), 5.00 (sept, $J=6.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.59 (br s, 2H), 1.28 (d, $J=6.0 \mathrm{~Hz}, 12 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 155.5,155.2,147.3,132.6,129.5,123.6,89.3,82.4,71.1,70.2,41.1,40.5$, 22.04, 21.99; HR-EIMS calcd for $\mathrm{C}_{17} \mathrm{H}_{21} \mathrm{~N}_{3} \mathrm{O}_{6}\left(\mathrm{M}^{+}\right)$363.1430. Found 363.1450; Anal. Calcd for $\mathrm{C}_{17} \mathrm{H}_{21} \mathrm{~N}_{3} \mathrm{O}_{6}$ : C, 56.19; H, 5.83; N, 11.56. Found C, 56.19; H, 5.85; N, 11.61.

## Diisopropyl 1-(3-(2-thienyl)-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1f)

According to GP1, 1f ( $754 \mathrm{mg}, 83 \%$ ) was obtained from 3-(2-thienyl)-2-propyn-1-ol ${ }^{3}$ ( $387 \mathrm{mg}, 2.81 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}$ ( $884 \mathrm{mg}, 3.37$ mmol), and DIAD ( $679 \mu \mathrm{~L}, 3.37 \mathrm{mmol}$ ). Eluent: hexane $/ \mathrm{AcOEt}=3 / 1$. Colorless crystals; m.p. $72.5-75.0^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}: 3518$ (N-H), 3410 (N-H), 2986 (C-H), 1714 (C=O), 1606 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$


1f NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.25$ (dd, $J=5.0,1.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.21 (dd, $J=3.5,1.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 6.97 (dd, $J=5.5,1.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 6.64 (br s, $5 / 7 \mathrm{H}$ ), 6.42 (br s, $2 / 7 \mathrm{H}$ ), 4.99 (sept, $J=6.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.56 (br s, 2 H ), 1.28 (d, $J=6.0 \mathrm{~Hz}, 12 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 155.3$ (2C), 132.4, 127.3, 126.9, 122.5, 87.6, 77.5, 70.8, 70.0, 40.5, 22.04, 21.98; HR-CIMS calcd for $\mathrm{C}_{15} \mathrm{H}_{20} \mathrm{~N}_{2} \mathrm{O}_{4} \mathrm{~S}\left(\mathrm{M}+\mathrm{H}^{+}\right)$ 325.1220. Found 325.1215; Anal. calcd for $\mathrm{C}_{15} \mathrm{H}_{19} \mathrm{~N}_{2} \mathrm{O}_{4} \mathrm{~S}$ : C, 55.54; H, 6.21; N, 8.64; S, 9.88. Found C, 55.62; H, 6.21; N, 8.67; S, 9.74.

Diisopropyl 1-(3-(3-thienyl)-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1g)
According to GP1, 1g (326 mg, 33\%) was obtained from 3-(3-thienyl)-2-propyn-1-ol ${ }^{6}$ ( $420 \mathrm{mg}, 3.04 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}$ ( $957 \mathrm{mg}, 3.65$ mmol), and DIAD ( $707 \mu \mathrm{~L}, 3.65 \mathrm{mmol}$ ). Eluent: hexane $/ \mathrm{AcOEt}=3 / 1$. Colorless oil; IR $v_{\text {max }}$ : 3413 (N-H), 3019 (C-H), 1712 (C=O), 1605 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.44$ (sd, $J=1.0 \mathrm{~Hz}, 1 \mathrm{H}$ ),


1 g 7.25 (dd, $J=5.0,3.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.09 (dd, $J=5.0,1.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 6.73 (br s, $3 / 4 \mathrm{H}$ ), 6.54 (br s, $1 / 4 \mathrm{H}$ ), 4.98 (sept, $J=6.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.53 (br s, 2H), 1.27 (d, $J=6.0 \mathrm{~Hz}, 12 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( 125 MHz , $\mathrm{CDCl}_{3}$ ) $\delta 155.3$ (2C), 129.8, 129.1, 125.3, 121.6, 83.1, 79.3, 70.7, 69.9, 41.1, 40.2, 22.0, 21.9; HR-EIMS calcd for $\mathrm{C}_{15} \mathrm{H}_{20} \mathrm{~N}_{2} \mathrm{O}_{4} \mathrm{~S}\left(\mathrm{M}^{+}\right)$324.1144. Found 324.1137.

## Diisopropyl 1-(3-(1-tosyl-3-indolyl)-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1h)

According to GP1, 1h ( $215 \mathrm{mg}, 52 \%$ ) was obtained from 3-(4-methoxyphenyl)-2-propyn-1-ol ( $250 \mathrm{mg}, 0.804 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}$ ( $253 \mathrm{mg}, 0.964 \mathrm{mmol}$ ), and DIAD ( $187 \mu \mathrm{~L}, 0.904 \mathrm{mmol}$ ). Eluent: hexane $/$ AcOEt $=1 / 1$.
Colorless amorphous solid; IR $v_{\text {max }}$ : 3412 (N-H), 2986 (C-H), 1730
 (C=O), 1600 (aryl), $1378\left(\mathrm{SO}_{2}\right), 1104\left(\mathrm{SO}_{2}\right) \mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $\left.500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta 7.96(\mathrm{~d}, \mathrm{~J}=8.5$ $\mathrm{Hz}, 1 \mathrm{H}$ ), 7.76 (d, $J=8.5 \mathrm{~Hz}, 2 \mathrm{H}), 7.72(\mathrm{~s}, 3 \mathrm{H}), 7.60(\mathrm{~d}, J=8.0 \mathrm{~Hz}, 1 \mathrm{H}), 7.35(\mathrm{td}, J=8.0,1.0 \mathrm{~Hz}$, 1 H ), 7.28 (td, $J=8.0,1.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.21 (d, $J=8.0 \mathrm{~Hz}, 2 \mathrm{H}), 6.75$ (br s, $2 / 3 \mathrm{H}$ ), 6.56 (br s, $1 / 3 \mathrm{H}$ ), 4.99 (sept, $J=6.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.61 (br s, 2H), 1.27 (d, $J=6.0 \mathrm{~Hz}, 12 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( 125 MHz , $\mathrm{CDCl}_{3}$ ) $\delta 155.3$ (2C), 145.4, 134.8, 134.1, 130.7, 130.00, 129.95, 129.3, 126.9, 125.5, 123.8, 120.5, 113.6, 104.5, 75.4, 70.8, 70.0, 40.9, 40.6, 22.04, 21.97, 21.6; HR-EIMS calcd for $\mathrm{C}_{26} \mathrm{H}_{29} \mathrm{~N}_{3} \mathrm{O}_{6} \mathrm{~S}$ $\left(\mathrm{M}^{+}\right)$511.1777. Found 511.1797.

## Diisopropyl 1-(3-(1-cyclohexenyl)-2-propyn-1-yl)hydrazine-1,2-dicarboxylate (1i)

According to GP1, 1i (801 mg, 65\%) was obtained from 3-(1-cyclohexenyl)-2-propyn-1-ol ${ }^{7}$ ( $520 \mathrm{mg}, 3.82 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}(1.20 \mathrm{~g}$, $4.59 \mathrm{mmol})$, and DIAD ( $888 \mu \mathrm{~L}, 4.59 \mathrm{mmol}$ ). Eluent: hexane/AcOEt $=$ 5/1.

$1 i$

Colorless oil; IR $v_{\max }$ : 3518 (N-H), 3412 (N-H), 2936 (C-H), 1713 (C=O), 1607 (aryl) cm ${ }^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 6.61$ (br s, 1 H ), 6.11-6.09 (m, 1H), 4.98 (sept, $J=6.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.42 (br s, 2H), 2.09-2.08 (m, 4H), 1.63-1.56 (m, 4H), 1.27 (d, J = 6.0 Hz, $12 \mathrm{H}){ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 155.4,135.5,120.1,86.1,80.6,72.3,70.6,69.8,41.1,40.2$, 29.1, 25.6, 22.2, 22.03, 22.00, 21.5; HR-EIMS calcd for $\mathrm{C}_{17} \mathrm{H}_{26} \mathrm{~N}_{2} \mathrm{O}_{4}\left(\mathrm{M}^{+}\right)$; 322.1893. Found 322.1909.

## Diisopropyl 1-(2-heptyn-1-yl)hydrazine-1,2-dicarboxylate (1j)

According to GP1, $\mathbf{1 j}$ ( $778 \mathrm{mg}, 98 \%$ ) was obtained from 2-heptyn-1-ol ( $300 \mathrm{mg}, 2.67 \mathrm{mmol}$ ), $\mathrm{Ph}_{3} \mathrm{P}(838 \mathrm{mg}, 3.20 \mathrm{mmol}$ ), and DIAD ( $621 \mu \mathrm{~L}$, $3.20 \mathrm{mmol})$. Eluent: hexane/AcOEt $=5 / 1$.
Colorless oil; IR $v_{\max }$ : 3413 (N-H), $2982(\mathrm{C}-\mathrm{H}), 1710(\mathrm{C}=\mathrm{O}) \mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$


1j

NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 6.58$ (br s, $5 / 6 \mathrm{H}$ ), 6.36 (br s, $1 / 6 \mathrm{H}$ ), 4.96 (sept, $J=6.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 4.29 (br s, 2H), 2.18 (tt, J = 7.5 $2.5 \mathrm{~Hz}, 2 \mathrm{H}$ ), 1.51-1.45 (m, 2H), 1.43-1.36 (m, 2H), 1.27 (d, J = 6.0 Hz , 12H), 0.91 (t, $J=7.5 \mathrm{~Hz}, 3 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 155.4$ (2C), 84.9, 74.0, 70.6, 69.8, 39.9, 30.7, 22.03, 21.99, 21.9, 18.4, 13.6; HR-EIMS calcd for $\mathrm{C}_{15} \mathrm{H}_{29} \mathrm{~N}_{2} \mathrm{O}_{4}\left(\mathrm{M}^{+}\right)$298.1893. Found 298.1908.

## General Procedure for the Preparation of Propargylic Hydrazides 1k-l via Propargylic Bromides (GP2)


$R^{2}$



1k-I
To a solution of diisopropyl hydrazodicarboxylate (1.1 equiv), which was prepared according to ethyl congener, ${ }^{8}$ in dry THF under Ar at $0^{\circ} \mathrm{C}$ was added NaH ( 1.15 equiv). The resulting solution was stirred at $0^{\circ} \mathrm{C}$ for 15 min and then propargylic bromide (1 equiv) and KI (1.2 equiv) was added at the same temperature. The mixture was refluxed overnight, quenched with $\mathrm{H}_{2} \mathrm{O}$, and extracted with $\mathrm{Et}_{2} \mathrm{O}$. The organic layer was dried over $\mathrm{Na}_{2} \mathrm{SO}_{4}$, filtered, and evaporated in vacuo. The residue was purified by flash column chromatography on silica gel eluting with hexane/AcOEt to give 1.

## Diisopropyl 1-(4-phenyl-3-butyn-2-yl)hydrazine-1,2-dicarboxylate (1k)

According to GP2, $\mathbf{1 k}(910 \mathrm{mg}, 91 \%)$ was obtained from 2-bromo-4-phenyl-3-butyne ( $627 \mathrm{mg}, 3.00 \mathrm{mmol}$ ), diisopropyl hydrazodicarboxylate ( $674 \mathrm{mg}, 3.30 \mathrm{mmol}$ ), $\mathrm{NaH}(138 \mathrm{mg}, 3.45 \mathrm{mmol}$ ), and KI ( $598 \mathrm{mg}, 3.60 \mathrm{mmol}$ ). Eluent: hexane/AcOEt = 3/1.
Colorless crystals; m.p. $63.0-65.0{ }^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}: 3504$


1k
(N-H), 3397 (N-H), 2986 (C-H), 1709 (C=O), 1600 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ 7.41 (m, 2H), 7.30 (m, 3H), 6.45 (br s, 4/5H), 6.29 (br s, $1 / 5 \mathrm{H}$ ), 5.34 (br s, 1H), 4.98 (sept, $J=6.0$ $\mathrm{Hz}, 2 \mathrm{H}), 1.51(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 3 \mathrm{H}), 1.28(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 12 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 156.1$, 154.8, 131.8, 128.4, 128.3, 122.6, 87.5, 83.4, 70.6, 69.7, 46.7, 22.1, 22.0, 19.6; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{24} \mathrm{~N}_{2} \mathrm{O}_{4}\left(\mathrm{M}^{+}\right)$332.1736. Found 332.1747; Anal. Calcd for $\mathrm{C}_{18} \mathrm{H}_{24} \mathrm{~N}_{2} \mathrm{O}_{4}$ : C, 65.04; H, 7.28; N, 8.43. Found C, 65.19; H, 7.30; N, 8.39.

## 2,5-Bis(3-(diisopropoxycarbonyl)hydrazino)-1-propyn-1-yl)thiophene (11)

According to GP2, $1 \mathbf{1}$ ( $135 \mathrm{mg}, 24 \%$ ) was obtained from 2,5-bis-(3-bromo-1-propynyl)thiophene ( 318 mg , 1.00 mmol ), ${ }^{9}$ diisopropyl hydrazodicarboxylate (449 $\mathrm{mg}, 2.20 \mathrm{mmol}$ ), $\mathrm{NaH}(92.0 \mathrm{mg}, 2.30 \mathrm{mmol})$, and KI
 ( $398 \mathrm{mg}, 2.40 \mathrm{mmol}$ ). Eluent: hexane $/ \mathrm{AcOEt}=3 / 1$.
Pale yellow amorphous solid; IR $v_{\text {max }}$ : 3539 (N-H), 3404 (N-H), 2986 (C-H), 1717 (C=O), 1605 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.03$ (s, 2H), 6.64 (br s, 1 H ), 6.42 (br s, 3/5H), 6.35 (br s, 2/5H), 4.99 (sept, $J=6.0 \mathrm{~Hz}, 4 \mathrm{H}$ ), 4.55 (br s, 4H), 1.28 (d, $J=6.0 \mathrm{~Hz}, 12 \mathrm{H}$ ), 1.27 (d, $J=6.0 \mathrm{~Hz}$, $12 \mathrm{H}){ }^{13} \mathrm{C}$ NMR (125 MHz, $\mathrm{CDCl}_{3}$ ) $\delta 155.2$ (2C), 132.1, 123.9, 88.6, 76.6, 70.9, 70.1, 40.6, 22.03,
21.99; HR-EIMS calcd for $\mathrm{C}_{26} \mathrm{H}_{36} \mathrm{~N}_{4} \mathrm{O}_{8} \mathrm{~S}\left(\mathrm{M}^{+}\right)$564.2254. Found 564.2277.

## General Procedure for the Preparation of Dihydropyrazole 2 by Iodocyclization (Condition A in Table 2, GP3)



To a solution of 1 (1 equiv) in dry $\mathrm{CH}_{2} \mathrm{Cl}_{2}(0.1 \mathrm{M})$ was added $\left.\mathrm{I}(\mathrm{coll})\right)_{2} \mathrm{PF}_{6}$ (2 equiv) at room temperature and the reaction mixture was stirred for 30 min . The reaction mixture was quenched with saturated aqueous solution of $\mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3}$, and was extracted with $\mathrm{CH}_{2} \mathrm{Cl}_{2}$. The organic layer was dried over $\mathrm{Na}_{2} \mathrm{SO}_{4}$, filtered, and evaporated in vacuo. The residue was purified by flash column chromatography on silica gel eluting with hexane/AcOEt to give 2 .

## Diisopropyl 2,5-dihydro-4-iodo-3-phenyl-1H-pyrazole-1,2-dicarboxylate (2a)

According to GP3, 2a ( $66.0 \mathrm{mg}, 85 \%$ ) was obtained from 1a ( 55.5 mg , 0.174 mmol ) and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(179 \mathrm{mg}, 0.349 \mathrm{mmol})$. Eluent: hexane/AcOEt = 5/1.
Colorless crystals; m.p. $105.5-107.0{ }^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}: 2986$ (C-H), 1720 (C=O), 1633 (C=C), 1602 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( 300 MHz ,


2a $\mathrm{CDCl}_{3}$ ) $\delta 7.58-7.55(\mathrm{~m}, 2 \mathrm{H}), 7.39(\mathrm{dd}, J=5.1,2.1 \mathrm{~Hz}, 3 \mathrm{H}$ ), 5.07 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.79 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}), 4.57(\mathrm{br} \mathrm{s}, 2 \mathrm{H}), 1.35(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}), 1.01(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 6 \mathrm{H}){ }^{13} \mathrm{C}$ NMR (75 $\mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 157.4,154.0,143.1,131.5,129.0,128.7,127.9,70.9,70.8,68.7,61.0,22.0,21.5 ;$ HR-EIMS calcd for $\mathrm{C}_{17} \mathrm{H}_{21} \mathrm{IN}_{2} \mathrm{O}_{2}\left(\mathrm{M}^{+}\right) 444.0563$. Found 444.0546; Anal. calcd for $\mathrm{C}_{17} \mathrm{H}_{21} \mathrm{IN}_{2} \mathrm{O}_{2}$ : C, 45.96; H, 4.76; N, 6.31. Found C, 45.88; H, 4.66; N, 6.28.

## Diisopropyl 2,5-dihydro-4-iodo-3-(2-methoxyphenyl)-1H-pyrazole-1,2-dicarboxylate (2b)

According to GP3, 2b ( 52.7 mg , quant) was obtained from $\mathbf{1 b}$ ( 38.6 mg , $0.111 \mathrm{mmol})$ and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(114 \mathrm{mg}, 0.222 \mathrm{mmol})$. Eluent: hexane $/$ AcOEt $=3 / 1$.
Colorless crystals; m.p. $105-107^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}$ : $2985(\mathrm{C}-\mathrm{H})$, 1714 (C=O), 1643 (C=C), 1597 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ )


2b
$\delta 7.37(\mathrm{td}, J=8.0,1.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.31(\mathrm{dd}, J=8.0,1.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.97(\mathrm{td}, J=7.5,1.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.92$ (d, $J=8.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 5.06 (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.77 (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.70-4.40 (br s, 2H), $3.84(\mathrm{~s}, 3 \mathrm{H}), 1.34(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}), 0.97(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 157.6,157.0,153.2,141.1,130.9,130.6,121.1,120.0,111.0,70.7,70.2,60.4$ (2C), 55.5, 22.1, 21.5; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{23} \mathrm{IN}_{2} \mathrm{O}_{5}\left(\mathrm{M}^{+}\right)$474.0652. Found 474.0661; Anal. calcd for

## Diisopropyl 2,5-dihydro-4-iodo-3-(3-methoxyphenyl)-1H-pyrazole-1,2-dicarboxylate (2c)

 According to GP3, 2c ( $36.1 \mathrm{mg}, 79 \%$ ) was obtained from 1c (34.0 $\mathrm{mg}, 0.0976 \mathrm{mmol})$ and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(100 \mathrm{mg}, 0.195 \mathrm{mmol})$. Eluent: hexane $/$ AcOEt $=4 / 1$.Colorless oil; IR $v_{\text {max }} 2985$ (C-H), 1720 (C=O), 1583 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR $\left(300 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta 7.31(\mathrm{t}, J=8.1 \mathrm{~Hz}, 1 \mathrm{H}), 7.17-7.12$


2c (m, 2H), 6.92 (dd, $J=8.1,1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 5.06 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.81 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.57 (br s, 2H), 3.83 (s, 3H), 1.34 (d, $J=6.3 \mathrm{~Hz}, 6 \mathrm{H}$ ), 1.04 (d, $J=6.3 \mathrm{~Hz}, 6 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( 75 MHz , $\left.\mathrm{CDCl}_{3}\right) \delta 159.1$ (2C), 154.0, 143.0, 132.7, 129.0, 121.2, 114.9, 114.0, 77.2, 70.8, 69.0, 61.0, 55.3, 22.0, 21.5; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{23} \mathrm{IN}_{2} \mathrm{O}_{5}\left(\mathrm{M}^{+}\right)$474.0652. Found 474.0672.

## Diisopropyl 2,5-dihydro-4-iodo-3-(4-methoxyphenyl)-1H-pyrazole-1,2-dicarboxylate (2d)

According to GP3, 2d (16.6 mg, 78\%) was obtained from 1d (16.7 $\mathrm{mg}, 0.0480 \mathrm{mmol}$ ) and $\mathrm{I}(\text { coll })_{2} \mathrm{PF}_{6}$ ( $49.4 \mathrm{mg}, 0.0960 \mathrm{mmol}$ ). Eluent: hexane $/ \mathrm{AcOEt}=4 / 1$.
Colorless oil; IR $v_{\text {max }} 2986$ (C-H), 1718 (C=O), 1609 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H} \operatorname{NMR}\left(300 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta 7.52$ (dd, $\left.J=6.9,2.1 \mathrm{~Hz}, 2 \mathrm{H}\right), 6.92$


2d (dd, $J=6.9,2.1 \mathrm{~Hz}, 2 \mathrm{H}$ ), 5.06 (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.81 (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.55 (br s, 2H), $3.84(\mathrm{~s}, 3 \mathrm{H}), 1.34(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}), 1.06(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ 160.0, 157.3, 154.1, 142.9, 130.2, 123.8, 113.3, 70.8, 70.7, 67.2, 60.8, 55.2, 22.0, 21.6; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{23} \mathrm{IN}_{2} \mathrm{O}_{5}\left(\mathrm{M}^{+}\right) 474.0652$. Found 474.0650.

## Diisopropyl 2,5-dihydro-4-iodo-3-(4-nitrophenyl)-1H-pyrazole-1,2-dicarboxylate (2e)

According to GP3, 2e ( $8.2 \mathrm{mg}, 23 \%$ ) was obtained from $\mathbf{1 e}$ ( 26.6 $\mathrm{mg}, 0.0732 \mathrm{mmol}$ ) and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(75.3 \mathrm{mg}, 0.146 \mathrm{mmol})$. Eluent: hexane $/$ AcOEt $=4 / 1$.
Colorless oil; IR $v_{\text {max }}$ : 3020 (C-H), 1733 (C=O), 1600 (aryl), 1523 $\left(\mathrm{NO}_{2}\right), 1347\left(\mathrm{NO}_{2}\right) \mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.27$ (dd, $J$
 $=9.0,2.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 7.76 (dd, $J=9.0,2.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), 5.08 (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.82 (sept, $J=6.0$ Hz, 1H), 4.68 (br s, 2H), 1.36 (d, $J=6.0 \mathrm{~Hz}, 6 \mathrm{H}$ ), 1.07 (d, $J=6.0 \mathrm{~Hz}, 6 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( 75 MHz , $\left.\mathrm{CDCl}_{3}\right) \delta 157.2,154.0,147.6,141.4,137.9,129.5,123.4,72.6,71.6,71.2,61.4,22.0,21.6 ;$ HR-ESIMS calcd for $\mathrm{C}_{11} \mathrm{H}_{21} \mathrm{IN}_{3} \mathrm{O}_{6}\left(\mathrm{M}+\mathrm{H}^{+}\right)$490.04750. Found 490.04703.

## Diisopropyl 2,5-dihydro-4-iodo-3-(2-thienyl)-1H-pyrazole-1,2-dicarboxylate (2f)

According to GP3, 2f ( $51.6 \mathrm{mg}, 88 \%$ ) was obtained from $\mathbf{1 f}(42.0 \mathrm{mg}$, $0.130 \mathrm{mmol})$ and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(133 \mathrm{mg}, 0.259 \mathrm{mmol})$. Eluent: hexane $/$ AcOEt $=4 / 1$.
Colorless crystals; m.p. $79.5-82.0{ }^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}: 2993$

$2 f$ (C-H), 1766 (C=O), 1654 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.44$ (dd, $J=4.0,1.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.42 (dd, $J=5.0,1.0 \mathrm{~Hz}, 1 \mathrm{H}), 7.07$ (dd, $J=5.0,1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 5.04 (sept, $J=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 4.87$ (sept, $J=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 4.74-4.40(\mathrm{br} \mathrm{m}, 2 \mathrm{H}), 1.32(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}), 1.13$ (d, $J=6.5 \mathrm{~Hz}, 6 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 157.1,154.5,138.5,132.7,129.3,127.1,126.6$, 71.1, 70.8, 70.1, 60.8, 21.9, 21.6; HR-EIMS calcd for $\mathrm{C}_{15} \mathrm{H}_{19} \mathrm{IN}_{2} \mathrm{O}_{4} \mathrm{~S}\left(\mathrm{M}^{+}\right)$450.0110. Found 450.0126; Anal. calcd for $\mathrm{C}_{15} \mathrm{H}_{19} \mathrm{IN}_{2} \mathrm{O}_{2} \mathrm{~S}$ : C, 40.01; H, 4.25; N, 6.22; S, 7.12. Found C, 40.04; H, 4.24; N, 6.23; S, 6.89.

## Diisopropyl 2,5-dihydro-4-iodo-3-(3-thienyl)-1H-pyrazole-1,2-dicarboxylate (2g)

According to GP3, 2g ( $32.2 \mathrm{mg}, 84 \%$ ) was obtained from $\mathbf{1 g}$ ( 27.6 mg , 0.0851 mmol ) and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(87.6 \mathrm{mg}, 0.176 \mathrm{mmol})$. Eluent: hexane $/ \mathrm{AcOEt}=4 / 1$.
Colorless oil; IR $v_{\max }$ : $2986(\mathrm{C}-\mathrm{H}), 1721(\mathrm{C}=\mathrm{O}), 1633(\mathrm{C}=\mathrm{C}) \mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.72-7.71(\mathrm{~m}, 1 \mathrm{H}), 7.31(\mathrm{~d}, J=2.1 \mathrm{~Hz}, 2 \mathrm{H})$,

$2 g$ 5.05 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.84 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.54 (br s, 2H), 1.33 (d, $J=6.3 \mathrm{~Hz}, 6 \mathrm{H}$ ), 1.09 (d, $J=6.3 \mathrm{~Hz}, 6 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 154.3$ (2C), 139.2, 131.7, 128.0, 126.0, 124.6, 70.9, 70.8, 68.5, 60.6, 22.0, 21.6; HR-EIMS calcd for $\mathrm{C}_{15} \mathrm{H}_{19} \mathrm{IN}_{2} \mathrm{O}_{4} \mathrm{~S}\left(\mathrm{M}^{+}\right) 450.0110$. Found 450.0113.

## Diisopropyl 2,5-dihydro-4-iodo-3-(1-tosyl-3-indolyl)-1H-pyrazole-1,2-dicarboxylate (2h)

According to GP3, $\mathbf{2 h}$ ( $31.3 \mathrm{mg}, 83 \%$ ) was obtained from $\mathbf{1 h}$ ( 30.0 mg , 0.0586 mmol ) and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(60.3 \mathrm{mg}, 0.117 \mathrm{mmol})$. Eluent: hexane $/ \mathrm{AcOEt}=4 / 3$.
Colorless crystals; m.p. $136.0-137.8^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }} 2930$ (C-H), 1735 (C=O), 1663 (C=C), 1600 (aryl), $1381\left(\mathrm{SO}_{2}\right), 1179\left(\mathrm{SO}_{2}\right)$


2h $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.07(\mathrm{~s}, 1 \mathrm{H}), 7.95(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.85(\mathrm{~d}, J=8.5 \mathrm{~Hz}$, 3 H ), 7.33 (td, $J=8.5,1.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.23 (d, $J=8.5 \mathrm{~Hz}, 2 \mathrm{H}$ ), 7.23 (d, $J=8.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 5.08 (sept, $J$ $=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 4.76(\mathrm{br} \mathrm{s}, 1 \mathrm{H}), 4.65(\mathrm{sept}, J=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 4.42(\mathrm{br} \mathrm{s}, 1 \mathrm{H}), 2.34(\mathrm{~s}, 3 \mathrm{H}), 1.37(\mathrm{~d}, J$ $=6.5 \mathrm{~Hz}, 6 \mathrm{H}$ ), 0.78 (br s, 3H), $0.50(\mathrm{br} \mathrm{s}, 3 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 157.7,153.2,145.3$, 136.6, 134.8, 134.3, 130.0, 129.5, 127.0, 126.4, 125.2, 123.7, 121.4, 113.4, 71.2, 70.9, 69.8, 22.0, 21.6, 21.4, 20.7; HR-EIMS calcd for $\mathrm{C}_{26} \mathrm{H}_{28} \mathrm{IN}_{3} \mathrm{O}_{6} \mathrm{~S}\left(\mathrm{M}^{+}\right)$637.0743. Found 637.0759; Anal. calcd for $\mathrm{C}_{26} \mathrm{H}_{28} \mathrm{IN}_{3} \mathrm{O}_{6} \mathrm{~S}$ : C, 48.99; H, 4.43; N, 6.59; S, 5.03. Found C, 49.14; H, 4.59; N, 6.47; S, 4.84.

## Diisopropyl 3-(1-cyclohexenyl)-2,5-dihydro-4-iodo-1H-pyrazole-1,2-dicarboxylate (2i)

According to GP3, 2i ( $20.4 \mathrm{mg}, 54 \%$ ) was obtained from $\mathbf{1 i}$ ( 27.0 mg , $0.0838 \mathrm{mmol})$ and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(86.2 \mathrm{mg}, 0.168 \mathrm{mmol})$. Eluent: hexane $/ \mathrm{AcOEt}=4 / 1$.
Colorless oil; IR $v_{\text {max }}$ : $2985(\mathrm{C}-\mathrm{H}), 1711(\mathrm{C}=\mathrm{O}), 1623(\mathrm{C}=\mathrm{C}) \mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 6.06-6.04(\mathrm{~m}, 1 \mathrm{H}), 4.98$ (sept d, $J=6.0,1.5$


2i Hz, 2H), 4.52 (br s, 2H), 2.18 (br s, 4H), 1.68 (br s, 4H), 1.28 (d, $J=7.2 \mathrm{~Hz}, 6 \mathrm{H}$ ), 1.26 (d, $J=6.3$ $\mathrm{Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 157.3,153.6,144.9,131.7,129.7,70.6,66.1,60.0,29.5$, 26.7, 25.3, 22.4, 21.92, 21.89, 21.85; HR-EIMS calcd for $\mathrm{C}_{17} \mathrm{H}_{25} \mathrm{IN}_{2} \mathrm{O}_{4}\left(\mathrm{M}^{+}\right) 448.0859$. Found 448.0871 .

## Diisopropyl 3-butyl-2,5-dihydro-4-iodo-1H-pyrazole-1,2-dicarboxylate (2j)

According to GP3, $\mathbf{2 j} \mathbf{( 2 6 . 8 ~ m g , ~ 6 0 \% ) ~ w a s ~ o b t a i n e d ~ f r o m ~} \mathbf{1 j}$ ( $31.5 \mathrm{mg}, 0.106$ mmol ) and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}$ ( $109 \mathrm{mg}, 0.211 \mathrm{mmol}$ ). Eluent: hexane $/ \mathrm{AcOEt}=4 / 1$. Colorless oil; IR $v_{\text {max }}$ : $2931(\mathrm{C}-\mathrm{H}), 1694(\mathrm{C}=\mathrm{O}), 1640(\mathrm{C}=\mathrm{C}) \mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 4.94$ (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.93 (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.47 (s, 2H), $2.54(\mathrm{t}, J=7.0 \mathrm{~Hz}, 2 \mathrm{H}), 1.57-1.49(\mathrm{~m}, 2 \mathrm{H}), 1.37(\mathrm{~d}, J=6.0 \mathrm{~Hz}$,


2j 6 H ), 1.27 (d, $J=6.0 \mathrm{~Hz}, 6 \mathrm{H}), 0.93(\mathrm{t}, J=7.0 \mathrm{~Hz}, 3 \mathrm{H}), 0.91-0.88(\mathrm{~m}, 2 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( 75 MHz , $\mathrm{CDCl}_{3}$ ) $\delta 159.2$ (2C), 151.0, 74.3, 69.9, 56.3, 37.4, 29.7, 28.5, 22.1, 21.9, 21.2, 13.9; HR-EIMS calcd for $\mathrm{C}_{15} \mathrm{H}_{25} \mathrm{IN}_{2} \mathrm{O}_{4}\left(\mathrm{M}^{+}\right)$424.0859. Found 424.0851.

## Diisopropyl 2,5-dihydro-4-iodo-5-methyl-3-phenyl-1H-pyrazole-1,2-dicarboxylate (2k)

According to GP3, 2k ( 47.8 mg , 97\%) was obtained from 1k ( 35.8 mg , $0.108 \mathrm{mmol})$ and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(111 \mathrm{mg}, 0.216 \mathrm{mmol})$. Eluent: hexane $/$ AcOEt $=4 / 1$.
Colorless oil; IR $v_{\text {max }}$ : $2985(\mathrm{C}-\mathrm{H}), 1710(\mathrm{C}=\mathrm{O}), 1633(\mathrm{C}=\mathrm{C}) \mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.57$ (dd, $J=7.5,1.0 \mathrm{~Hz}, 2 \mathrm{H}$ ), $7.41-7.36(\mathrm{~m}, 3 \mathrm{H}), 5.07$


2k (sept, $J=6.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.85 (q, $J=6.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.80 (sept, $J=6.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 1.50 (d, $J=6.0 \mathrm{~Hz}$, $3 \mathrm{H}), 1.35$ (d, $J=6.5 \mathrm{~Hz}, 3 \mathrm{H}$ ), 1.34 (d, $J=7.5 \mathrm{~Hz}, 6 \mathrm{H}), 1.00(\mathrm{~d}, J=6.5 \mathrm{~Hz}, 3 \mathrm{H}){ }^{13} \mathrm{C}$ NMR (125 $\mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 156.9,154.6,142.5,131.6,129.0,128.8,127.9,76.0,70.6,70.5,67.5,22.1,22.0$, 21.5, 21.4, 18.5; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{23} \mathrm{IN}_{2} \mathrm{O}_{4}\left(\mathrm{M}^{+}\right) 458.0703$. Found 458.0712.

## 2,5-Bis(2,5-dihydro-1,2-di(isopropoxycarbonyl)-4-iodo-1H-pyrazol-3-yl)thiophene (2l)

According to GP3, $\mathbf{2 l}$ ( $26.6 \mathrm{mg}, 84 \%$ ) was obtained from $1 \mathbf{l}$ ( $22.2 \mathrm{mg}, 0.0393 \mathrm{mmol}$ ) and $\mathrm{I}(\mathrm{coll})_{2} \mathrm{PF}_{6}(80.9 \mathrm{mg}, 0.157$ mmol ). Eluent: hexane $/ \mathrm{AcOEt}=3 / 2$.
Yellow oil; IR $v_{\text {max }} 2985$ (C-H), 1722 (C=O), 1628 (C=C) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.39$ (s, 2H), 5.04 (sept,

$J=6.3 \mathrm{~Hz}, 2 \mathrm{H}), 4.89(\mathrm{sept}, J=6.3 \mathrm{~Hz}, 2 \mathrm{H}), 4.57(\mathrm{br} \mathrm{s}, 4 \mathrm{H}), 1.34(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 12 \mathrm{H}), 1.32$ (d, $J=$ $6.3 \mathrm{~Hz}, 12 \mathrm{H}$ ); ${ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 157.0,154.5,138.3,134.0,128.9,71.4,71.2,70.9$, 60.9, 22.0, 21.6; HR-CIMS calcd for $\mathrm{C}_{26} \mathrm{H}_{34} \mathrm{I}_{2} \mathrm{~N}_{4} \mathrm{O}_{8} \mathrm{~S}\left(\mathrm{M}+\mathrm{H}^{+}\right)$817.0265. Found 817.0263.

General Procedure for the Preparation of Pyrazole 3 by Iodocyclization (Condition B in Table 2, GP4)


To a solution of 1 (1 equiv) in dry $\mathrm{CH}_{2} \mathrm{Cl}_{2}$ ( 0.1 M ) was added NIS (3 equiv) followed by $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}$ (3 equiv) at $0{ }^{\circ} \mathrm{C}$, and the reaction mixture was stirred for 10 min . The reaction mixture was quenched with saturated aqueous solution of $\mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3}$, and was extracted with $\mathrm{CH}_{2} \mathrm{Cl}_{2}$. The organic layer was dried over $\mathrm{Na}_{2} \mathrm{SO}_{4}$, filtered, and evaporated in vacuo. The residue was purified by flash column chromatography on silica gel eluting with hexane/AcOEt to give 3.

## Isopropyl 4-iodo-5-phenyl-1H-pyrazole-1-carboxylate (3a)

According to GP4, 3a ( $29.0 \mathrm{mg}, 84 \%$ ) was obtained from 1a ( $31.0 \mathrm{mg}, 0.0973$ mmol ), NIS ( $65.7 \mathrm{mg}, 0.292 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(36.0 \mu \mathrm{~L}, 0.292 \mathrm{mmol})$. Eluent: hexane/AcOEt $=5 / 1$.
Colorless oil; IR $v_{\text {max }}$ : 2994 (C-H), 1766 (C=O), 1617 (aryl) cm ${ }^{-1} ;{ }^{1} \mathrm{H}$ NMR (500 $\mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.28(\mathrm{~s}, 1 \mathrm{H}), 7.82$ (dd, $J=8.0,1.2 \mathrm{~Hz}, 2 \mathrm{H}$ ), 7.45-7.43 (m, 3H),


3a 5.30 (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), $1.46(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 156.1,147.7$, 137.3, 131.2, 129.3, 128.7, 128.3, 73.7, 62.7, 21.7; HR-EIMS calcd for $\mathrm{C}_{13} \mathrm{H}_{13} \mathrm{IN}_{2} \mathrm{O}_{2}\left(\mathrm{M}^{+}\right)$ 356.0022. Found 356.0036.

## Isopropyl 4-iodo-5-(2-methoxyphenyl)-1H-pyrazole-1-carboxylate (3b)

According to GP4, 3b (14.5 mg, 99\%) was obtained from 1b (13.1 mg, 0.0376 mmol ), NIS ( $25.4 \mathrm{mg}, 0.113 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(14.0 \mu \mathrm{~L}, 0.113$ $\mathrm{mmol})$. Eluent: hexane $/ \mathrm{AcOEt}=4 / 1$.
Colorless crystals; m.p. 103.2-104.0 ${ }^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}$ : 2998 (C-H),
 1752 (C=O), 1608 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.26(\mathrm{~s}, 1 \mathrm{H})$, 7.42 (td, $J=7.5,2.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.37 (dd, $J=7.5,2.0 \mathrm{~Hz}, 1 \mathrm{H}), 7.02(\mathrm{td}, J=7.5,1.0 \mathrm{~Hz}, 1 \mathrm{H}), 6.79$ (d, $J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.29(\mathrm{sept}, J=6.0 \mathrm{~Hz}, 1 \mathrm{H}), 3.82(\mathrm{~s}, 3 \mathrm{H}), 1.44(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR (125 $\mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 157.4,157.0,147.9,136.1,131.6,131.0,120.5,120.4,110.9,73.5,67.1,55.4$, 21.7; HR-EIMS calcd for $\mathrm{C}_{14} \mathrm{H}_{15} \mathrm{IN}_{2} \mathrm{O}_{3}\left(\mathrm{M}^{+}\right)$386.0127. Found 386.0127; Anal. calcd for $\mathrm{C}_{14} \mathrm{H}_{15} \mathrm{IN}_{2} \mathrm{O}_{3}$ : C, 43.54; H, 3.91; N, 7.25. Found C, 43.78; H, 3.87; N, 7.38.

## Isopropyl 4-iodo-5-(3-methoxyphenyl)-1H-pyrazole-1-carboxylate (3c)

According to GP4, 3c ( $20.0 \mathrm{mg}, 74 \%$ ) was obtained from 1c ( 24.4 mg , 0.0700 mmol ), NIS ( $47.3 \mathrm{mg}, 0.210 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(26.0 \mu \mathrm{~L}$, $0.210 \mathrm{mmol})$. Eluent: hexane $/ \mathrm{AcOEt}=5 / 1$.
Colorless oil; IR $v_{\text {max }}$ : 3014 (C-H), 1765 (C=O), 1588 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.28(\mathrm{~s}, 1 \mathrm{H}), 7.47$ (dt, $J=8.1,1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ),
 7.41 (dd, $J=2.7,1.2 \mathrm{~Hz}, 1 \mathrm{H}$ ), $7.36(\mathrm{t}, J=8.1 \mathrm{~Hz}, 1 \mathrm{H}), 6.98$ (ddd, $J=8.1,2.7,1.2 \mathrm{~Hz}, 1 \mathrm{H}), 5.30$ (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), $3.87(\mathrm{~s}, 3 \mathrm{H}), 1.46(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 159.4$, 155.9, 147.8, 137.3, 132.4, 129.3, 121.1, 115.4, 113.7, 73.7, 62.8, 55.4, 21.7; HR-EIMS calcd for $\mathrm{C}_{14} \mathrm{H}_{15} \mathrm{IN}_{2} \mathrm{O}_{3}\left(\mathrm{M}^{+}\right)$386.0127. Found 386.0128.

## Isopropyl 4-iodo-5-(4-methoxyphenyl)-1H-pyrazole-1-carboxylate (3d)

According to GP4, 3d ( 35.9 mg , quant) was obtained from 1d ( 32.5 mg , 0.0933 mmol ), NIS ( $84.0 \mathrm{mg}, 0.373 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(46.0 \mu \mathrm{~L}$, 0.373 mmol ). Eluent: hexane $/$ AcOEt $=3 / 1$.

Colorless oil; IR $v_{\text {max }}$ : $3014(\mathrm{C}-\mathrm{H}), 1765(\mathrm{C}=\mathrm{O}), 1613$ (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.25(\mathrm{~s}, 1 \mathrm{H}), 7.84(\mathrm{~d}, J=9.0 \mathrm{~Hz}, 2 \mathrm{H}), 6.97$


3d (d, $J=9.0 \mathrm{~Hz}, 2 \mathrm{H}), 5.29$ (sept, $J=6.0 \mathrm{~Hz}, 1 \mathrm{H}), 3.85(\mathrm{~s}, 3 \mathrm{H}), 1.46(\mathrm{~d}, J=6.0 \mathrm{~Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 160.0,155.8,147.9,137.2,130.0,123.7,113.7,73.6,62.7,55.3,21.7$; HR-EIMS calcd for $\mathrm{C}_{14} \mathrm{H}_{15} \mathrm{IN}_{2} \mathrm{O}_{3}\left(\mathrm{M}^{+}\right) 386.0127$. Found 386.0128.

## Isopropyl 4-iodo-5-(2-thienyl)-1H-pyrazole-1-carboxylate (3f)

According to GP4, 3f ( 46.8 mg , $91 \%$ ) was obtained from $\mathbf{1 f}(46.0 \mathrm{mg}, 0.142$ mmol ), NIS ( $95.8 \mathrm{mg}, 0.426 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(52.6 \mu \mathrm{~L}, 0.426 \mathrm{mmol})$. Eluent: hexane/AcOEt $=5 / 1$.
Colorless crystals; m.p. $90.2-91.2{ }^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}: 2993$ (C-H),


3f 1766 (C=O), 1649 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.24$ (s, 1 H ), 7.89 (dd, $J=3.6,1.2$ $\mathrm{Hz}, 1 \mathrm{H}$ ), 7.41 (dd, $J=5.4,1.2 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.12 (dd, $J=5.4,3.9 \mathrm{~Hz}, 1 \mathrm{H}$ ), 5.28 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), $1.46(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 6 \mathrm{H}){ }^{13} \mathrm{C}$ NMR $\left(75 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta 151.1,147.6,137.5,133.1,127.9,127.34$, 127.31, 73.8, 61.7, 21.7; HR-EIMS calcd for $\mathrm{C}_{11} \mathrm{H}_{11} \mathrm{IN}_{2} \mathrm{O}_{2} \mathrm{~S}\left(\mathrm{M}^{+}\right)$361.9586. Found 361.9599; Anal. Calcd for $\mathrm{C}_{11} \mathrm{H}_{11} \mathrm{IN}_{2} \mathrm{O}_{2} \mathrm{~S}: \mathrm{C}, 36.48$; H, 3.06; N, 7.73; S, 8.85. Found C, 36.72; H, 3.02; N, 7.82; S, 8.78.

## Isopropyl 4-iodo-5-(3-thienyl)-1H-pyrazole-1-carboxylate (3g)

According to GP4, $\mathbf{3 g}$ ( $29.0 \mathrm{mg}, 90 \%$ ) was obtained from $\mathbf{1 g}$ ( $33.3 \mathrm{mg}, 0.103$ mmol ), NIS ( $69.4 \mathrm{mg}, 0.308 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(38.0 \mu \mathrm{~L}, 0.308 \mathrm{mmol})$. Eluent: hexane/AcOEt $=5 / 1$.
Colorless crystals; m.p. 85.0-86.8 ${ }^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}: 2993(\mathrm{C}-\mathrm{H})$,


1765 (C=O), 1605 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.24$ (s, 1 H ), 8,10 (dd, $J=3.0,1.5$ $\mathrm{Hz}, 1 \mathrm{H}$ ), 7.73 (dd, $J=5.1,1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.38 (dd, $J=5.1,3.0 \mathrm{~Hz}, 1 \mathrm{H}$ ), 5.28 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), $1.46(\mathrm{~d}, \mathrm{~J}=6.0 \mathrm{~Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 152.0,147.8,137.2,132.2,127.5,125.6$, 125.3, 73.7, 62.1, 21.7; HR-EIMS calcd for $\mathrm{C}_{11} \mathrm{H}_{11} \mathrm{IN}_{2} \mathrm{O}_{2} \mathrm{~S}\left(\mathrm{M}^{+}\right)$361.9586. Found 361.9592; Anal. calcd for $\mathrm{C}_{11} \mathrm{H}_{11} \mathrm{IN}_{2} \mathrm{O}_{2} \mathrm{~S}$ : C, 36.48; H, 3.06; N, 7.73; S, 8.85. Found C, 36.59; H, 3.01; N, 7.80; S, 8.72.

## Isopropyl 4-iodo-5-(1-tosyl-3-indolyl)-1H-pyrazole-1-carboxylate (3h)

According to GP4, 3h ( $31.3 \mathrm{mg}, 87 \%$ ) was obtained from $\mathbf{1 h}$ ( 33.0 mg , 0.0645 mmol ), NIS ( $43.9 \mathrm{mg}, 0.195 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(24.1 \mu \mathrm{~L}, 0.195$ mmol ). Eluent: hexane $/ \mathrm{AcOEt}=3 / 1$.
Colorless oil; IR $v_{\text {max }} 2992(\mathrm{C}-\mathrm{H}), 1756(\mathrm{C}=\mathrm{O}), 1600\left(\right.$ aryl), $1378\left(\mathrm{SO}_{2}\right)$, $1176\left(\mathrm{SO}_{2}\right) \mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.45(\mathrm{~s}, 1 \mathrm{H}), 8.30(\mathrm{~s}, 1 \mathrm{H})$,


3h 8.23 (dd, $J=6.9,1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 8.01 (dd, $J=7.2,1.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 7.81 (d, $J=8.4 \mathrm{~Hz}, 2 \mathrm{H}$ ), 7.39-7.29 (m, 2H), 7.22 (d, $J=8.1 \mathrm{~Hz}, 2 \mathrm{H}$ ), 5.29 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 2.34 (s, 3H), 1.47 (d, $J=6.3 \mathrm{~Hz}$, $1 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 150.4,147.8,145.2,136.8,134.9,134.7,129.9,128.9,126.9$, 126.3, 125.3, 124.1, 122.9, 113.9, 113.3, 73.7, 62.9, 21.7, 21.6; HR-EIMS calcd for $\mathrm{C}_{22} \mathrm{H}_{20} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{~S}$ $\left(\mathrm{M}^{+}\right)$549.0219. Found 549.0222.

## Isopropyl 5-(1-cyclohexenyl)-4-iodo-1H-pyrazole-1-carboxylate (3i)

According to GP4, $\mathbf{3 i}$ ( $33.2 \mathrm{mg}, 70 \%$ ) was obtained from $\mathbf{1 i}$ ( $42.5 \mathrm{mg}, 0.132$ mmol), NIS ( $74.2 \mathrm{mg}, 0.330 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(40.7 \mu \mathrm{~L}, 0.330 \mathrm{mmol})$. Eluent: hexane/AcOEt = 10/1.
Colorless oil; IR $v_{\text {max }}$ : 2936 (C-H), 1764 (C=O), 1612 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.14(\mathrm{~s}, 1 \mathrm{H}), 6.55-6.51(\mathrm{~m}, 1 \mathrm{H}), 5.25$ (sept, $J=6.0 \mathrm{~Hz}$,

$3 i$ $1 \mathrm{H})$, 2.51-2.46 (m, 2H), 2.26-2.19 (m, 2H), 1.79-1.62 (m, 4H), $1.43(\mathrm{~d}, \mathrm{~J}=6.0 \mathrm{~Hz}, 6 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 157.0,147.9,136.8,131.5,129.5,73.3,61.8,27.0,25.4,22.4,21.7$; HR-EIMS calcd for $\mathrm{C}_{13} \mathrm{H}_{17} \mathrm{IN}_{2} \mathrm{O}_{2}\left(\mathrm{M}^{+}\right) 360.0335$. Found 360.0327.

## Isopropyl 5-butyl-4-iodo-1H-pyrazole-1-carboxylate (3j)

According to GP4, $\mathbf{3 j}$ ( $14.6 \mathrm{mg}, \mathbf{2 8 \%}$ ) was obtained from $\mathbf{1 j}$ ( $45.8 \mathrm{mg}, 0.154$ mmol ), NIS ( $138.1 \mathrm{mg}, 0.614 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(75.8 \mu \mathrm{~L}, 0.614 \mathrm{mmol}$ ). Eluent: hexane/AcOEt $=10 / 1$.
Colorless oil; IR $v_{\text {max }}$ : 2929 (C-H), 1762 (C=O), 1607 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR (500


3j $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta 8.10(\mathrm{~s}, 1 \mathrm{H}), 5.26$ (sept, $\left.J=6.5 \mathrm{~Hz}, 1 \mathrm{H}\right), 2.65(\mathrm{t}, J=8.0 \mathrm{~Hz}, 2 \mathrm{H})$, 1.67 (quint, $J=7.5 \mathrm{~Hz}, 2 \mathrm{H}$ ), 1.43 (sext, $J=7.5 \mathrm{~Hz}, 2 \mathrm{H}$ ), 1.43 (d, $J=6.5 \mathrm{~Hz}, 6 \mathrm{H}$ ), 0.94 (t, $J=7.5$ $\mathrm{Hz}, 3 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 159.2,147.8,135.8,73.3,65.4,30.7,27.8,22.5,21.7$, 13.8; HR-EIMS calcd for $\mathrm{C}_{11} \mathrm{H}_{17} \mathrm{IN}_{2} \mathrm{O}_{4}\left(\mathrm{M}^{+}\right)$336.0335. Found 336.0341.

## Isopropyl 4-iodo-3-methyl-5-phenyl-1H-pyrazole-1-carboxylate (3k)

According to GP4, 3k ( 29.4 mg , 80\%) was obtained from $\mathbf{1 k}$ ( $32.8 \mathrm{mg}, 0.0987$ mmol ), NIS ( $66.6 \mathrm{mg}, 0.296 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(36.5 \mu \mathrm{~L}, 0.296 \mathrm{mmol})$. Eluent: hexane/AcOEt $=5 / 1$.
Colorless crystals; m.p. 63.0-65.0 ${ }^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }} 2992(\mathrm{C}-\mathrm{H}), 1750$ (C=O), 1618 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.83-7.80(\mathrm{~m}, 2 \mathrm{H})$,


3k 7.46-7.42 (m, 3H), 5.27 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}), 2.70(\mathrm{~s}, 3 \mathrm{H}), 1.47(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 6 \mathrm{H}){ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 154.6,149.3,146.3,131.9,129.1,128.8,128.2,73.3,68.7,21.7,15.7$; HR-EIMS calcd for $\mathrm{C}_{14} \mathrm{H}_{15} \mathrm{IN}_{2} \mathrm{O}_{2}\left(\mathrm{M}^{+}\right)$370.0178. Found 370.0192; Anal. calcd for $\mathrm{C}_{11} \mathrm{H}_{11} \mathrm{IN}_{2} \mathrm{O}_{2} \mathrm{~S}$ : C, 45.42; H, 4.08; N, 7.57. Found C, 45.24; H, 3.84; N, 7.64.

2,5-Bis(4-iodo-1-isopropoxycarbonyl-1H-pyrazol-5-yl)thiophene (3l)
According to GP4, $3 \mathbf{1}(23.0 \mathrm{mg}, 53 \%)$ was obtained from $\mathbf{1 b}$ ( 38.6 mg , 0.0684 mmol ), NIS ( $92.3 \mathrm{mg}, 0.410 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(50.6 \mu \mathrm{~L}$, 0.410 mmol ). Eluent: hexane $/ \mathrm{AcOEt}=3 / 1$.

Colorless crystals; m.p. $196.3-198.0^{\circ} \mathrm{C}$ (hexane/AcOEt); IR $v_{\text {max }}: 2990$


31 (C-H), 1764 (C=O), 1646 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.26$ (s, 2H), $7.90(\mathrm{~s}, 2 \mathrm{H})$, 5.29 (sept, $J=6.3 \mathrm{~Hz}, 2 \mathrm{H}$ ), 1.47 (d, $J=6.3 \mathrm{~Hz}, 12 \mathrm{H}) ;{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 147.8,137.9$, 135.0, 128.3, 100.2, 74.2, 61.8, 22.0; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{18} \mathrm{I}_{2} \mathrm{~N}_{4} \mathrm{O}_{4} \mathrm{~S}\left(\mathrm{M}^{+}\right)$639.9138. Found 639.9152.

## Isopropyl 4-bromo-5-phenyl-1H-pyrazole-1-carboxylate (4a)

According to GP4, 4a (149 mg, 49\%) was obtained from 1a ( $216 \mathrm{mg}, 0.677$ mmol ), NBS ( $362 \mathrm{mg}, 2.03 \mathrm{mmol}$ ), and $\mathrm{BF}_{3} \cdot \mathrm{OEt}_{2}(251 \mu \mathrm{~L}, 2.03 \mathrm{mmol})$. Eluent: hexane/AcOEt $=4 / 1$.
Colorless oil; IR $v_{\text {max }}$ : 2993 (C-H), 1767 (C=O), 1624 (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR (300 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta 8.23(\mathrm{~s}, 1 \mathrm{H}), 7.93(\mathrm{dd}, J=7.5,2.1 \mathrm{~Hz}, 2 \mathrm{H}), 7.46-7.42(\mathrm{~m}, 3 \mathrm{H})$,

$4 a$ 5.30 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 1.47 (d, $J=6.3 \mathrm{~Hz}, 6 \mathrm{H}$ ), ${ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 153.3,148.0$, 132.3, 130.4, 129.3, 128.33, 128.28, 97.0, 73.8, 21.8; HR-ESIMS calcd for $\mathrm{C}_{13} \mathrm{H}_{13} \mathrm{IN}_{2} \mathrm{O}_{2}\left(\mathrm{M}+\mathrm{H}^{+}\right)$ 309.0239. Found 309.0227.

## Diisopropyl 2,5-dihydro-3-phenyl-4-(2-thienyl)-1H-pyrazole-1,2-dicarboxylate (5)

Dihydropyrazole 2a ( $40.0 \mathrm{mg}, 0.0900 \mathrm{mmol}$ ), 2-thiopheneboronic acid (16.1 $\mathrm{mg}, 0.126 \mathrm{mmol}), \mathrm{Pd}(\mathrm{dba})_{2}(2.6 \mathrm{mg}, 4.50 \mu \mathrm{~mol})$, and $\mathrm{Ph}_{3} \mathrm{P}(4.7 \mathrm{mg}, 180$ $\mu \mathrm{mol}$ ) were placed into the Schlenk-flask with reflux condenser and bubble-counter. This set-up was evacuated and filled with argon several times. After THF ( 4 mL ) and $20 \%$ aq. of $\mathrm{Na}_{2} \mathrm{CO}_{3}(4 \mathrm{~mL})$ were added, the


5 mixture was refluxed for 14 h . It was diluted AcOEt, and organic layer was separated and
evaporated in vacuo. The residue was purified by flash column chromatography on silica gel eluting with hexane $/$ AcOEt $=5 / 1$ to give 5 ( $34.1 \mathrm{mg}, 95 \%$ ).
Colorless oil; IR $v_{\text {max }} 2986(\mathrm{C}-\mathrm{H}), 1714$ (C=O), 1600 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.50-7.46(\mathrm{~m}, 2 \mathrm{H}), 7.43-7.40(\mathrm{~m}, 3 \mathrm{H}), 7.07(\mathrm{dd}, J=5.1,1.2 \mathrm{~Hz}, 1 \mathrm{H}), 6.09(\mathrm{dd}, J=5.1,3.6 \mathrm{~Hz}$, 1 H ), 6.86 (dd, $J=3.6,1.2 \mathrm{~Hz}, 1 \mathrm{H}$ ), 5.07 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.84 (br s, 2H), 4.80 (sept, $J=6.3$ $\mathrm{Hz}, 1 \mathrm{H}), 1.34(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 6 \mathrm{H}), 1.00(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 6 \mathrm{H}){ }^{13} \mathrm{C}$ NMR $\left(75 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta 157.6$, 154.3, 135.3, 134.1, 131.6, 129.6, 129.0, 128.3, 126.6, 125.5, 124.8, 114.6, 70.7, 70.3, 55.6, 22.0, 21.5; HR-ESIMS calcd for $\mathrm{C}_{21} \mathrm{H}_{24} \mathrm{~N}_{2} \mathrm{O}_{4} \mathrm{~S}\left(\mathrm{M}+\mathrm{H}^{+}\right)$401.15350. Found 401.15252.

## Diisopropyl

## 2,5-dihydro-4-((E)-2-(methoxycarbonyl)ethenyl)-3-phenyl-1H-pyrazole-1,2-dicarboxylate (6)

To a solution of $\mathbf{2 a}(40.4 \mathrm{mg}, 0.0909 \mathrm{mmol})$, methyl acrylate ( 29.7 mg , $0.246 \mathrm{mmol}), \mathrm{Et}_{3} \mathrm{~N}(40 \mu \mathrm{~L}, 0.273 \mathrm{mmol})$ in anhydrous $\mathrm{CH}_{3} \mathrm{CN}(1.0$ mL ) under Ar was added $\mathrm{PdCl}_{2}\left(\mathrm{PPh}_{3}\right)_{2}(3.8 \mathrm{mg}, 5.46 \mu \mathrm{~mol})$. The reaction mixture was heated to reflux for 4.5 h . After reaction completed, the mixture was quenched with saturated aqueous solution
 of $\mathrm{NH}_{4} \mathrm{Cl}$, extracted with $\mathrm{Et}_{2} \mathrm{O}$. The organic layer was dried over filtered $\mathrm{Na}_{2} \mathrm{SO}_{4}$, and evaporated in vacuo. The residue was purified by flash column chromatography on silica gel eluting with hexane $/$ AcOEt $=4 / 1$ to give 6 ( $30.1 \mathrm{mg}, 82 \%$ ).
Colorless oil; IR $v_{\text {max }}$ : $2985(\mathrm{C}-\mathrm{H}), 1712(\mathrm{C}=\mathrm{O}), 1618$ (aryl) $\mathrm{cm}^{-1} ;{ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ 7.43 (d, $J=16.2 \mathrm{~Hz}, 1 \mathrm{H}), 7.43$ (s, 5 H ), 5.77 (d, $J=15.6 \mathrm{~Hz}, 1 \mathrm{H}$ ), 5.07 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.81 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.66 (br s, 2H), 3.73 (s, 3H), 1.35 (d, $J=6.3 \mathrm{~Hz}, 6 \mathrm{H}$ ), 1.02 (d, $J=6.3 \mathrm{~Hz}$, 6 H ); ${ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ 167.1, 153.4 (2C), 145.3, 135.4, 130.3, 129.6, 129.1, 128.3, 118.7, 117.5, 71.02, 70.98, 53.2, 51.6, 22.0, 21.5; HR-EIMS calcd for $\mathrm{C}_{21} \mathrm{H}_{26} \mathrm{~N}_{2} \mathrm{O}_{6}\left(\mathrm{M}+\mathrm{H}^{+}\right)$; 403.1869. Found 403.1862.

Diisopropyl 2,5-dihydro-3-phenyl-4-((trimethylsilyl)ethynyl)-1H-pyrazole-1,2-dicarboxylate (7)

A solution of $2 \mathbf{2 a}(195 \mathrm{mg}, 0.439 \mathrm{mmol}$ ), ethynyltrimethylsilane ( $68 \mu \mathrm{~L}$, $0.483 \mathrm{mmol}), \mathrm{PdCl}_{2}\left(\mathrm{PPh}_{3}\right)_{2}(3.1 \mathrm{mg}, 4.39 \mu \mathrm{~mol}), \mathrm{CuI}(1.7 \mathrm{mg}, 8.78 \mu \mathrm{~mol})$ in $\mathrm{Et}_{3} \mathrm{~N}(10 \mathrm{~mL})$ was stirred for 12 h under Ar at room temperature. After reaction completed, the mixture was diluted with AcOEt, washed with $10 \% \mathrm{HCl}$ aq., dried over filtered $\mathrm{Na}_{2} \mathrm{SO}_{4}$, and evaporated in vacuo. The
 residue was purified by flash column chromatography on silica gel eluting with hexane/AcOEt $=$ $5 / 1$ to give 7 ( 182 mg , quant).
Colorless oil; IR $v_{\text {max }}$ : 2985 (C-H), 1723 (C=O), 1604 (aryl) $\mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 7.73-7.70(\mathrm{~m}, 2 \mathrm{H}), 7.37-7.34(\mathrm{~m}, 3 \mathrm{H}), 5.03$ (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.84 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 4.51 (br s, 2H), $1.32(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 6 \mathrm{H}), 1.07(\mathrm{~d}, J=6.3 \mathrm{~Hz}, 6 \mathrm{H}), 0.18(\mathrm{~s}, 9 \mathrm{H}){ }^{13} \mathrm{C}$ NMR ( 75 MHz ,
$\left.\mathrm{CDCl}_{3}\right) \delta 157.5$ (2C), 154.3, 146.3, 130.6, 129.1, 128.1, 127.5, 103.6, 103.0, 97.2, 70.9, 70.7, 55.0, 22.0, 21.5, -0.4; HR-EIMS calcd for $\mathrm{C}_{22} \mathrm{H}_{30} \mathrm{~N}_{2} \mathrm{O}_{4} \mathrm{Si}\left(\mathrm{M}^{+}\right)$; 414.1975. Found 414.1981.

## Isopropyl 5-phenyl-4-((trimethylsilyl)ethynyl)-1H-pyrazole-1-carboxylate (8)

A solution of $3 \mathbf{a}(46.1 \mathrm{mg}, 0.129 \mathrm{mmol})$, ethynyltrimethylsilane $(14.0 \mathrm{mg}$, $0.142 \mathrm{mmol}), \mathrm{PdCl}_{2}\left(\mathrm{PPh}_{3}\right)_{2}(0.91 \mathrm{mg}, 1.30 \mu \mathrm{~mol}), \mathrm{CuI}(0.49 \mathrm{mg}, 2.60 \mu \mathrm{~mol})$ in $\mathrm{Et}_{3} \mathrm{~N}(10 \mathrm{~mL})$ was stirred for 22 h under Ar at room temperature. After reaction completed, the mixture was diluted with AcOEt, washed with $10 \%$ HCl aq., dried over filtered $\mathrm{Na}_{2} \mathrm{SO}_{4}$, and evaporated in vacuo. The residue was
 purified by flash column chromatography on silica gel eluting with hexane/AcOEt = 5/1 to give 8 ( $28.3 \mathrm{mg}, 67 \%$ ).
Colorless oil; IR $v_{\text {max }}$ : $2928(\mathrm{C}-\mathrm{H}), 1765(\mathrm{C}=\mathrm{O}) \mathrm{cm}^{-1}$; ${ }^{1} \mathrm{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 8.29(\mathrm{~s}, 1 \mathrm{H})$, 8.21-8.18 (m, 2H), 7.42 (dd, $J=5.4,2.4 \mathrm{~Hz}, 3 \mathrm{H}$ ), 5.29 (sept, $J=6.3 \mathrm{~Hz}, 1 \mathrm{H}$ ), 1.46 (d, $J=6.3 \mathrm{~Hz}$, 6 H ), 0.26 (s, 9H); ${ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta 155.2,148.1,135.2,131.2,129.3,128.2,127.6$, 105.1, 99.9, 95.7, 73.6, 21.7, -0.3; HR-EIMS calcd for $\mathrm{C}_{18} \mathrm{H}_{22} \mathrm{~N}_{2} \mathrm{O}_{2} \mathrm{Si}\left(\mathrm{M}^{+}\right)$; 326.1451. Found 326.1470.








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## ${ }^{1} \mathrm{H}-{ }^{15} \mathrm{~N}$ HMBC NMR Studies and Spectra

For the determination of the position of carbamate group for pyrazole 3, we measured ${ }^{1} \mathrm{H}-{ }^{15} \mathrm{~N}$ HMBC NMR spectra for $N$-acetylpyrazole, $\mathbf{3 j}$ and $\mathbf{3 a}$. At first, we assigned acylated nitrogen atom by the NMR measurement of $N$-acetylpyrazole. This result indicated that acylated nitrogen atom $(-75.2 \mathrm{ppm})$ is lower field than non-acylated one ( -138.1 ppm ) in ${ }^{15} \mathrm{~N}$ NMR. Next, ${ }^{1} \mathrm{H}_{-}{ }^{15} \mathrm{~N}$ HMBC NMR spectra for $\mathbf{3 j}$ showed that $n$-butyl group-substituted carbon atom on pyrazole is adjacent to acylated nitrogen atom ( -80.6 ppm ). In addition, non-acylated nitrogen atom ( -161.6 ppm ) for $\mathbf{3 j}$ has a higher correlation with $3-\mathrm{H}(8.10 \mathrm{ppm})$ than acylated one ( -80.6 ppm ). This tendency also appeared for $\mathbf{3 a}$.

2.71

N -acetylpyrazole

3j



These ${ }^{1} \mathrm{H}-{ }^{15} \mathrm{~N}$ HMBC NMR spectra were shown as below.




## References

1) Mitsunobu, O.; Tamada, M.; Mukaiyama, T. Bull. Chem. Soc. Jpn. 1967, 40, 935-939.
2) (a) Sabby, S.; Bella, M.; Jørgensen, K. A. J. Am. Chem. Soc. 2004, 126, 8120-8121. (b) Liu, X.; Li, H.; Deng, L. Org. Lett. 2005, 7, 167-169. (c) Matsubara, R.; Kobayashi, S. Angew. Chem., Int. Ed. 2006, 45, 7993-7995. (d) He, R.; Wang, X.; Hashimoto, T.; Maruoka, K. Angew. Chem., Int. Ed. 2008, 47, 9466-9468. (e) Mashiko, T.; Kumagai, N.; Shibasaki, M. J. Am. Chem. Soc. 2009, 131, 14990-14999.
3) Franks, M. A.; Schrader, E. A.; Pietsch, E. C.; Pennella, D. R.; Torti, S. V.; Welker, M. E. Bioorg. Med. Chem. 2005, 13, 2221-2233.
4) Kwong, F. Y.; Li, Y. M.; Lam, W. H.; Qui, L.; Lee, H. W.; Yeung, C. H.; Chan, K. S.; Chan, A. S. S. Chem. Eur. J. 2005, 11, 3872-3880.
5) Sudeshna, S.; Dipankar, S.; Piyali, D.; Rima, L.; Amitabha, S. Tetrahedron 2009, 65, 4367-4374.
6) Bare, T. M. et al. J. Med. Chem. 2007, 50, 3113-3131.
7) Tessier, P. E.; Nguyen, N.; Clay, M. D.; Fallis, A. G. Org. Lett. 2005, 7, 767-770.
8) Rabjohn, N. Org. Synth. 1948, 28, 375-377.
9) Werner, C.; Hopf, H.; Dix, I.; Bubenitschek, P.; Jones, P. G. Chem. Eur. J. 2007, 13, 9462-9477.

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