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Condensation of Carboxylic Acids with Non-Nucleophilic *N*-Heterocycles and Anilides Using Boc_2O

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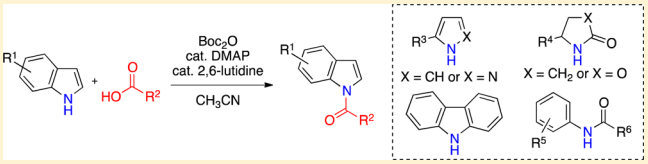
Supporting Information

ABSTRACT: A novel condensation reaction of carboxylic acids with various non-nucleophilic *N*-heterocycles and anilides was developed. The reaction proceeds in the presence of di-*tert*-butyl dicarbonate (Boc_2O), catalytic 4-(dimethylamino)pyridine (DMAP), and 2,6-lutidine and is applicable to the acylation of a wide range of non-nucleophilic nitrogen compounds, including indoles, pyrroles, pyrazole, carbazole, lactams, oxazolidinones, and anilides with high functional group compatibility. The scope of indoles, carboxylic acids, and anilides was also studied.



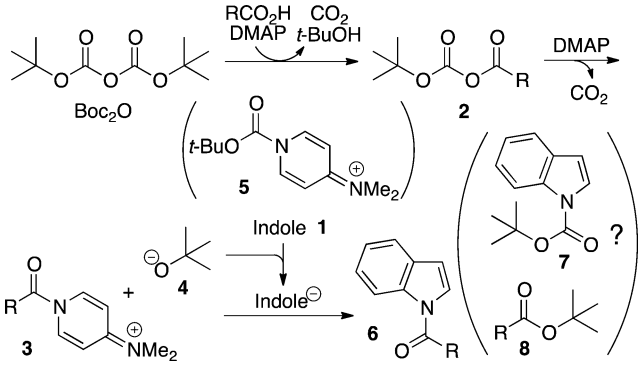
The amide group is one of the most important and fundamental functional groups present in naturally occurring compounds, proteins, synthetic polymers, and pharmaceutical agents. Therefore, the development of amide formation reactions has a long history, and numerous reaction conditions have so far been reported.[1] However, methodologies for the direct condensation of carboxylic acids with aromatic *N*-heterocycles such as indole, pyrrole, pyrazole, and carbazole are limited[2] due the low nucleophilicity of these substrates, which is attributed to the participation of the nitrogen lone pair electrons in the aromatic system. Direct condensation of lactams or anilides is also inefficient, due to the low nucleophilicity of nitrogen by delocalization of the nitrogen lone pair electrons into the carbonyl group.

In order to conduct condensation reactions of these non-nucleophilic nitrogen compounds with carboxylic acids, prior formation of an anionic species by deprotonation of the N−H by a stoichiometric strong metal base such as *n*-butyllithium or NaH and/or the use of an activated carboxylic acid derivative such as an acid halide or activated ester[3−5] is usually required. For example, Snider reported *N*-acylation of a tryptophan derivative by using a *p*-nitrophenyl ester as an acylation reagent.[6] Sarpong has recently demonstrated that carbonylazoles are effective for a highly chemoselective *N*-acylation of indoles and oxazolidinones.[7]

To consider a direct condensation of carboxylic acids and non-nucleophilic nitrogen compounds, we focused on the function of di-*tert*-butyl dicarbonate (Boc_2O). Installation of a *tert*-butyloxycarbonyl (Boc) group on a variety of non-nucleophilic nitrogen compounds including indoles, pyrroles, and lactams proceeds smoothly with a combination of Boc_2O and 4-(dimethylamino)pyridine (DMAP).[8] This process should include in situ generation of a *N*-Boc-dimethylaminopyridinium ion and naked *t*-butoxide.[8d] On the other hand, a combination of Boc_2O, DMAP, and tertiary amines or pyridine is effective for condensation of carboxylic acids with primary amines,[9a] anilines,[9b] ammonia,[9c] alcohols,[9d−g] or phenols,[9d] in which the corresponding mixed anhydride is initially formed.

We reasoned that upon mixing a non-nucleophilic nitrogen compound, such as indole (**1**), and a carboxylic acid in the presence of Boc_2O and DMAP, the above Boc-mediated processes would facilitate acylation to form *N*-acylated product **6** by activation of the carboxylic acid as a mixed anhydride **2** or *N*-acyl-dimethylaminopyridinium ion **3** and activation of the non-nucleophilic nitrogen compound as an anionic species (Scheme 1).[10] A competing process would be the formation of

Scheme 1. Working Hypothesis



N-Boc-indole[8b,c,e,f] **7** and/or a *t*-butyl ester[9e,g] **8** via reaction of the indole anion with *N*-Boc-dimethylaminopyridinium ion **5** or reaction of *t*-butoxide with mixed anhydride **2** or *N*-acyl-dimethylaminopyridinium ion **3**, respectively. To the best of our knowledge, Boc-mediated condensation has only been applied to intrinsically nucleophilic compounds[9] and there is no report on non-nucleophilic nitrogen compounds. Herein, we

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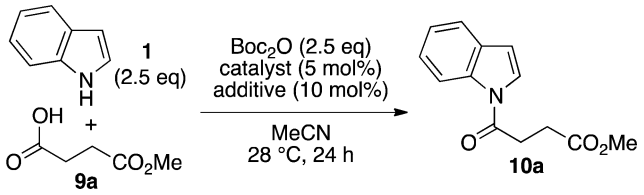
report a novel direct condensation of carboxylic acids with various non-nucleophilic aromatic *N*-heterocycles, lactams, oxazolidinones, and anilides under metal-free mild conditions using Boc_2O.

Keeping these considerations in mind, we examined the proposed Boc_2O-mediated amide formation using *mono*-methyl succinate (**9a**) and indole (**1**) as test substrates (Table 1). First,

Table 1. Optimization of Reaction Conditions



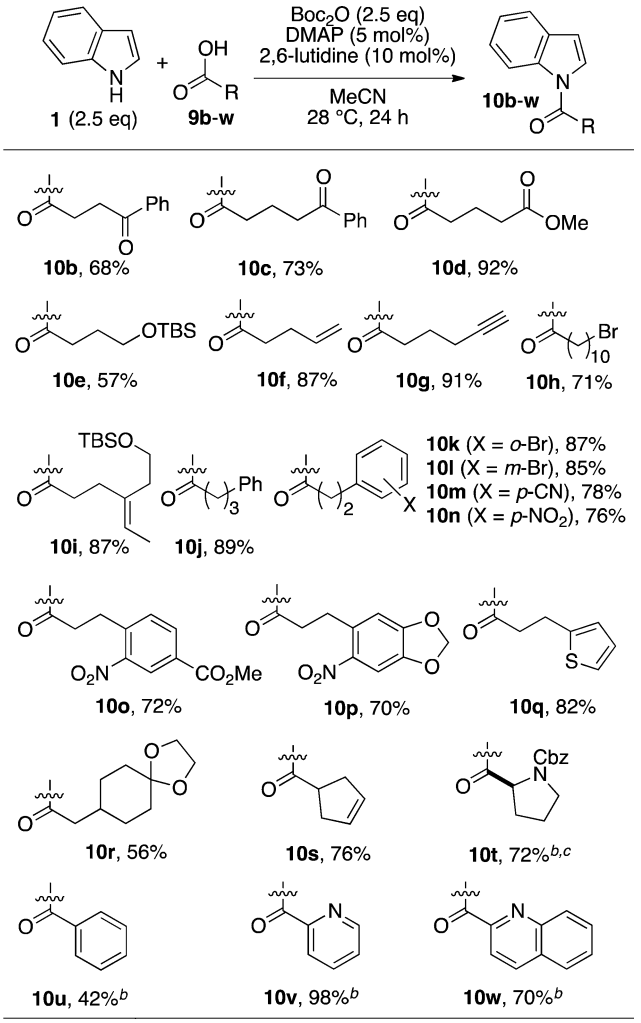
entry	catalyst	additive	yield (%)[a]
1	DMAP	–	42
2	NMI	–	33
3	DABCO	–	Trace
4	DBU	–	0
5	DMAP	Et_3N	87
6	DMAP	pyridine	88
7	DMAP	2,6-lutidine	92
8	DMAP	$NaHCO_3$	81
9	DMAP	Na_2CO_3	79
10	DMAP	K_2CO_3	89
11	DMAP	Cs_2CO_3	91
12	–	2,6-lutidine	0
13[b]	DMAP	2,6-lutidine	69
14[c]	DMAP	2,6-lutidine	65 (82)[d]
15[e]	DMAP	2,6-lutidine	97

[a]Isolated yield. [b]CH_2Cl_2 was used instead of MeCN. [c]Indole (1 equiv) and Boc_2O (1.5 equiv) were used. [d]On the basis of the recovered starting indole. [e]This reaction was performed on 5 g scale of **9a**.

we tested the conditions required for Boc protection of the indole N–H (entry 1). Thus, **1** was treated with **9a** in the presence of Boc_2O and 5 mol % DMAP. To our satisfaction, we obtained a moderate yield of the expected *N*-acylindole **10a** along with a trace amount of *N*-Boc-indole **7**, without the *t*-butyl ester of **9a** being formed. Reactions with other amine catalysts such as *N*-methylimidazole (NMI), 1,4-diazabicyclo[2.2.2]octane (DABCO), and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) (entries 2–4) did not give amide **10a** in better yields. Considering that protonation of DMAP with the carboxylic acid would prevent smooth conversion, we then added additional base to the reaction. A significant acceleration was observed when we added 10 mol % triethylamine to give **10a** in 87% yield (entry 5). Extensive examination revealed that 2,6-lutidine yielded the best result, thus affording the desired *N*-acylindole **10a** in 92% yield (entry 7). In addition, the reaction using inorganic bases proceeded smoothly to provide the desired product **10a** in high yields (entries 8–11). The reaction did not proceed without DMAP at all (entry 12), thus indicating that it plays a crucial role in this condensation reaction. The yield decreased when CH_2Cl_2 was used as the solvent instead of MeCN (entry 13). Excess indole and Boc_2O are also necessary for the high-yielding and selective formation of *N*-acylindole **10a**. Thus, a reaction using an equimolar amount of **1** with Boc_2O (1.5 equiv) gave **10a** in 65% yield along with *N*-Boc-indole **7** (14%) and recovery of **1** (21%) (entry 14). Moreover, we performed this reaction using 5 g of carboxylic acid **9a**. The reaction proceeded uneventfully to afford the target acyl indole **10a** in almost quantitative yield (entry 15).

Having established the optimal conditions, we then investigated the substrate scope of carboxylic acids (Table 2).

Table 2. Scope of Carboxylic Acids[a]



[a]Isolated yield. [b]DMAP (20 mol %) and 2,6-lutidine (30 mol %) were used. [c]>99% *ee*, determined by HPLC analysis.

Reactions using a series of functionalized linear carboxylic acids (**9b–q**) demonstrated that a variety of functional groups, including ketone, ester, silyl ether, alkenyl, alkynyl, bromoalkyl, substituted phenyl, and thienyl groups, were compatible with the reaction conditions to give the corresponding *N*-acylindoles **10b–q** in good to excellent yields. Sterically hindered *β*- (**9r**) or *α*-branched (**9s** and **9t**) carboxylic acids were feasible in the reaction to give **10r**, **10s**, and **10t** in good yields. In particular, *N*-benzyloxycarbonyl-proline derivative **10t** was obtained without loss of optical purity. Due to the relatively lower reactivity, reaction of aromatic carboxylic acids **9u–w** required increased amounts of the bases (20 mol % DMAP and 30 mol % 2,6-lutidine). Notably, heteroaromatic carboxylic acids, 2-pyridinecarboxylic acid (**9v**), and 2-quinolinecarboxylic acid (**9w**), reacted smoothly to provide *N*-acylindoles **10v** and **10w** in good to excellent yields.

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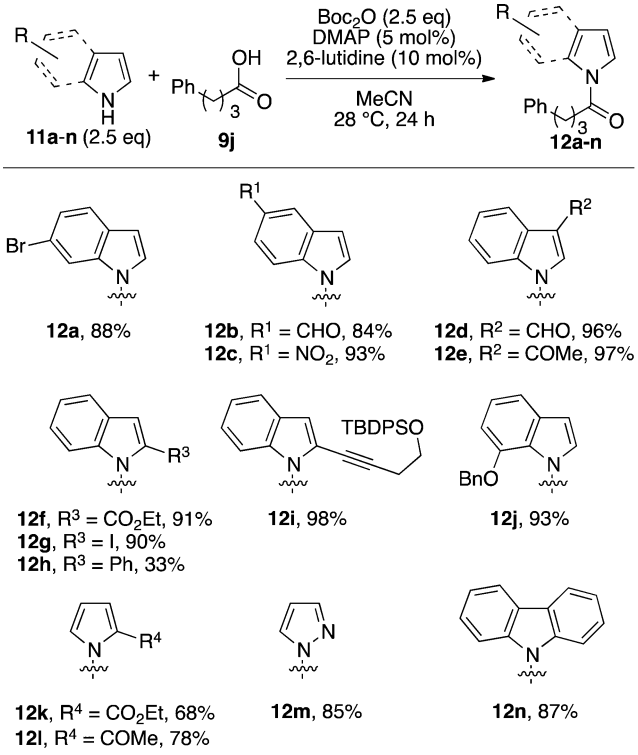
Next, the scope of non-nucleophilic nitrogen compounds was studied using 4-phenylbutyric acid (**9j**) (Table 3). Reaction of

Table 3. Scope of Indole Derivatives and *N*-Heteroaromatic Compounds[a]

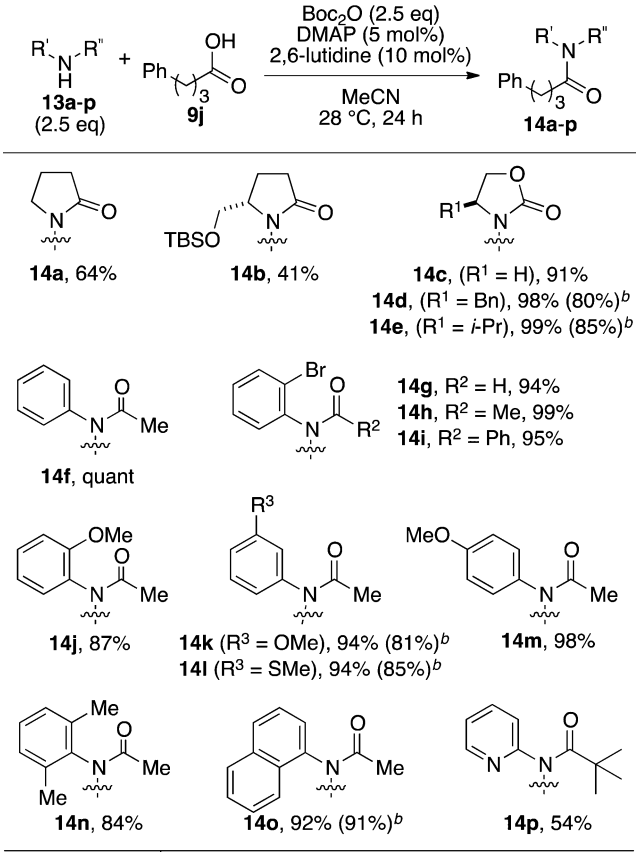


[a]Isolated yield.

6-, 5-, or 3-substituted indoles bearing halogen or electron-withdrawing groups proceeded well under the optimal conditions to provide *N*-acylindoles (**12a**–**e**) in excellent yields. Significantly, 2- and 7-substituted indoles, which usually behave as poor nucleophiles due to steric hindrance,[3f,7] gave the corresponding *N*-acylindoles (**12f**–**j**) in excellent yields, except for 2-phenylindole (**11h**). In addition to these indole derivatives, analogous non-nucleophilic *N*-heteroaromatic compounds such as pyrroles, pyrazole, and carbazole proved to be suitable substrates to give *N*-acyl products **12k**–**n** in good to excellent yields.

Furthermore, we found that this reaction was applicable to other non-nucleophilic nitrogen compounds including γ-lactams, oxazolidinones, and anilides. Thus, γ-lactams (**13a** and **13b**) and oxazolidinones (**13c**–**e**) reacted smoothly to provide the corresponding *N*-acyl products **14a**, **14b**, and **14c**–**e** (Table 4). The anilides (**13f**–**p**) bearing substituents at the *ortho*-, *meta*- or *para*-positions on the benzene ring gave the corresponding imides (**14f**–**p**) in nearly quantitative yields. Importantly, the sterically hindered substrate **13n** derived from 2,6-dimethylaniline reacted uneventfully to furnish the desired imide **14n** in a high yield. Finally, 1-aminonaphthalene derivative **13o** and 2-pyridylamide **13p** served as good substrates to give the desired products (**14o** and **14p**) in excellent and satisfactory yields, respectively. In the case of oxazolidinones (**13d** and **13e**) and anilides (**13k**, **13l**, and **13o**), reaction using an equimolar amount of the nucleophiles with Boc_2O (1.5 equiv) gave the products in high (80–91%) yields.

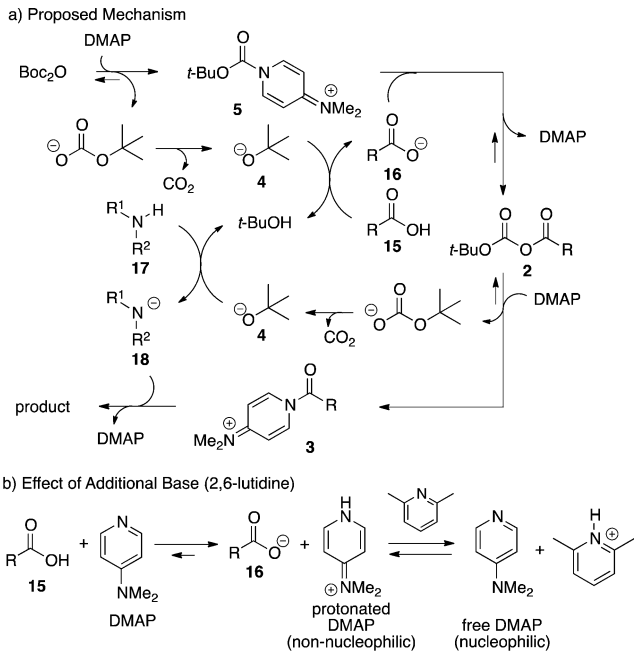
Table 4. Scope of Lactams, Oxazolidinones, and Anilides[a]



[a]Isolated yield. [b]Nucleophile (1 equiv) and Boc_2O (1.5 equiv) were used.

Plausible reaction mechanisms based on the above observations and related reports[9] are depicted in Scheme 2. The initial nucleophilic attack of DMAP on Boc_2O should give *N*-Boc-dimethylaminopyridinium ion **5** with concomitant

Scheme 2. Proposed Mechanism



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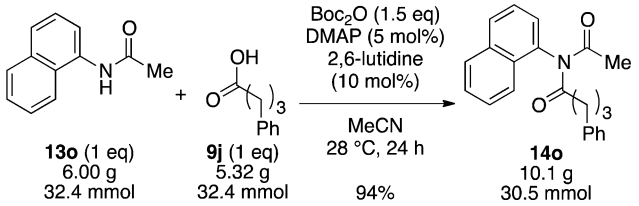
generation of a naked *t*-butoxide anion (**4**), which deprotonates carboxylic acid **15** to give carboxylate **16**, followed by addition of **16** to **5**, which would afford mixed anhydride **2**. Subsequent nucleophilic attack of DMAP on **2** should produce *N*-acyl-dimethylaminopyridinium ion **3** with formation of naked *t*-butoxide (**4**). At this point, non-nucleophilic nitrogen compound **17** should be deprotonated by **4** to afford a highly nucleophilic anion **18**. Finally, anion **18** would attack **3** to furnish the desired amide. Smooth acylation of non-nucleophilic nitrogen compounds **17** should be based on dual activation, namely, activation of carboxylic acid by conversion to the *N*-acyl-dimethylaminopyridinium ion **3** and deprotonation of N−H by naked *t*-butoxide (**4**). The key to the selective formation of amides, while circumventing possible competing processes (i.e., formation of *N*-Boc nitrogen compounds and *t*-butyl esters), is attributed to the higher reactivity of **3** among the three acyl donors **2**, **3**, and **5** due to steric as well as electronic reasons. According to the series of experiments in Table 1, we consider that the role of the additional base (2,6-lutidine) would be as a proton scavenger to prevent protonation of DMAP (Scheme 2b).

To demonstrate the practical synthetic utility of the direct condensation, we performed a multigram scale reaction (Scheme 3). Thus, acid **9j** and an equimolar amount of anilide

Scheme 3. Multigram Scale Reaction



13o with Boc_2O (1.5 equiv) were subjected to the reaction conditions. As expected, the condensation took place smoothly to furnish the desired product **14o** in 94% yield.

In conclusion, we have developed a direct condensation of carboxylic acids with a wide variety of non-nucleophilic *N*-heterocycles such as indoles, pyrroles, pyrazole, carbazole, lactams, and oxazolidinones using the Boc_2O/DMAP/2,6-lutidine system. Furthermore, various anilides were also amenable to this reaction and generated imides. The Boc_2O/DMAP/2,6-lutidine system played a crucial role in the in situ dual activation of both carboxylic acids as the *N*-acyl-dimethylaminopyridinium ion and of non-nucleophilic nitrogen compounds through the generation of the corresponding anion with naked *t*-butoxide. This condensation reaction is performed using a simple operation that does not involve prior formation of the anion by deprotonation of the nitrogen nucleophile using a metal base and preparation of an activated carboxylic acid such as an acid halide or activated ester.

EXPERIMENTAL SECTION

General Remarks. Materials were obtained from commercial suppliers and used without further purification unless otherwise mentioned. All reactions were carried out in oven-dried glassware under a slight positive pressure of argon unless otherwise noted. Column chromatography was performed on spherical neutral silica gel (63-210 μm), and flash column chromatography was performed on spherical neutral silica gel (40−50 μm) using the indicated eluent. Analytical TLC was performed on glass plates precoated with a 0.25 mm thickness of silica gel. All melting points were determined on a micro melting point apparatus and are uncorrected. ^1H NMR and ^{13}C NMR spectra were recorded at 400 and 600 MHz for ^1H NMR and (100 and 150 MHz for ^{13}C NMR. For ^1H NMR spectra, chemical shifts are given from tetramethylsilane (0 ppm) or chloroform (7.24 ppm) as an internal standard. For ^{13}C NMR spectra, chemical shifts are given from chloroform (77.0 ppm) as an internal standard. Mass spectra were realized by ESI method using a time-of-flight mass spectrometer.

General Synthetic Procedure of Condensation Reaction. *Methyl 4-(1H-indol-1-yl)-4-oxobutanoate (**10a**).* A 10 mL threaded Pyrex test tube equipped with a magnetic stirring bar, a rubber septum, and argon inlet needle was charged with Boc_2O (223 mg, 1.02 mmol). A solution of *mono*-methyl succinate (**9a**) (54.0 mg, 0.409 mmol), indole (**1**) (120 mg, 1.02 mmol), DMAP (2.5 mg, 0.02 mmol), and 2,6-lutidine (4.7 μL, 0.04 mmol) in MeCN (0.9 mL) were added to the test tube at room temperature. Then, the reaction mixture was warmed to 28 °C by water bath. After stirring at 28 °C for 24 h, the resulting mixture was concentrated under reduced pressure to give a crude oil, which was purified by silica gel column chromatography (hexanes/AcOEt = 5:1) to give *N*-acylindole **10a** (87.1 mg, 0.377 mmol, 92%); a white solid; mp 82−83 °C (hexanes-AcOEt); IR (neat) 2953, 1738, 1708, 1454, 1310, 1207, 910, 752 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.43 (d, *J* = 8.4 Hz, 1H), 7.56 (d, *J* = 7.8 Hz, 1H), 7.50 (d, *J* = 3.6 Hz, 1H), 7.34 (dd, *J* = 7.8, 6.6 Hz, 1H), 7.28 (dd, *J* = 8.4, 6.6 Hz, 1H), 6.66 (d, *J* = 3.6 Hz, 1H), 3.74 (s, 3H), 3.27 (t, *J* = 6.6 Hz, 2H), 2.86 (t, *J* = 6.6 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.8, 169.8, 135.6, 130.3, 125.2, 124.3, 123.7, 120.9, 116.5, 109.5, 52.0, 30.7, 28.3; HRMS Calcd for $C_{13}H_{13}NNaO_3$ [M + Na^+] 254.0793, found 254.0790.

*1-(1H-Indol-1-yl)-4-phenylbutane-1,4-dione (**10b**).* According to the general procedure described for **10a**, *N*-acylindole **10b** (79.4 mg, 0.287 mmol, 68%) was obtained from 3-benzolypropionic acid (**9b**) (75.0 mg, 0.421 mmol) and indole (**1**) (123 mg, 1.05 mmol); a white solid; mp 146−148 °C (hexanes-AcOEt); IR (neat) 2949, 1703, 1678, 1453, 1399, 1360, 1311, 1227, 1212, 773, 764, 751 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.43 (d, *J* = 8.4 Hz, 1H), 8.05 (d, *J* = 7.2 Hz, 2H), 7.60 (d, *J* = 4.2 Hz, 1H), 7.59 (d, *J* = 8.4 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 1H), 7.49 (dd, *J* = 8.4, 7.2 Hz, 2H), 7.33 (dd, *J* = 8.4, 6.6 Hz, 1H), 7.27 (dd, *J* = 8.4, 6.6 Hz, 1H), 6.68 (d, *J* = 4.2 Hz, 1H), 3.54 (t, *J* = 6.6 Hz, 2H), 3.41 (t, *J* = 6.6 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) 198.0, 170.4, 136.5, 135.7, 133.4, 130.4, 128.7, 128.1, 125.1, 124.6, 123.7, 120.8, 116.6, 109.4, 32.8, 29.8; HRMS Calcd for $C_{18}H_{15}NNaO_2$ [M + Na^+] 300.1000, found 300.0993.

*1-(1H-Indol-1-yl)-5-phenylpentane-1,5-dione (**10c**).* According to the general procedure described for **10a**, *N*-acylindole **10c** (71.4 mg, 0.245 mmol, 73%) was obtained from 4-benzoylbutyric acid (**9c**) (64.0 mg, 0.335 mmol) and indole (**1**) (98.0 mg, 0.836 mmol); a white solid; mp 98−100 °C (hexanes-AcOEt); IR (neat) 2949, 1704, 1685, 1451, 1388, 1338, 1308, 1224, 1209, 768, 750, 690 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.47 (d, *J* = 7.8 Hz, 1H), 7.99 (d, *J* = 7.8 Hz, 2H), 7.58−7.55 (m, 3H), 7.47 (dd, *J* = 8.4, 7.8 Hz, 2H), 7.35 (dd, *J* = 7.8, 7.8 Hz, 1H), 7.27 (dd, *J* = 7.8, 7.8 Hz, 1H), 6.64 (d, *J* = 3.6 Hz, 1H), 3.21 (t, *J* = 7.2 Hz, 2H), 3.07 (t, *J* = 7.2 Hz, 2H), 2.30 (tt, *J* = 7.2, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) 199.5, 171.1, 136.7, 135.6, 133.2, 130.4, 128.6, 128.0, 125.1, 124.7, 123.6, 120.8, 116.6, 109.2, 37.2, 34.9, 19.0; HRMS Calcd for $C_{19}H_{17}NNaO_2$ [M + Na^+] 314.1157, found 314.1152.

*Methyl 5-(1H-indol-1-yl)-5-oxopentanoate (**10d**).* According to the general procedure described for **10a**, *N*-acylindole **10d** (79.5 mg, 0.324 mmol, 92%) was obtained from glutaric acid *mono*-methyl ester (**9d**) (52.0 mg, 0.355 mmol) and indole (**1**) (104 mg, 0.887 mmol); a white solid; mp 49−51 °C (hexanes-AcOEt); IR (neat) 2953, 1735, 1706, 1453, 1310, 1207, 752 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.46 (d, *J* = 8.4 Hz, 1H), 7.56 (d, *J* = 7.8 Hz, 1H), 7.49 (d, *J* = 3.6 Hz, 1H), 7.35 (dd, *J* = 7.8, 7.8 Hz, 1H), 7.27 (dd, *J* = 8.4, 7.8 Hz, 1H), 6.64 (d, *J* = 3.6 Hz, 1H), 3.70 (s, 3H), 3.01 (t, *J* = 6.6 Hz, 2H), 2.53 (t, *J* = 6.6 Hz, 2H), 2.17 (tt, *J* = 6.6, 6.6 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.5, 170.7, 135.6, 130.3, 125.1, 124.5, 123.7, 120.8, 116.6, 109.2, 51.7, 34.7, 32.8, 19.7; HRMS Calcd for $C_{14}H_{15}NNaO_3$ [M + Na^+] 268.0950, found 268.0934.

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*4-((tert-Butyldimethylsilyl)oxy)-1-(1H-indol-1-yl)butan-1-one (**10e**).* According to the general procedure described for **10a**, *N*-acylindole **10e** (69.2 mg, 0.218 mmol, 57%) was obtained from carboxylic acid **9e**[11] (84.0 mg, 0.385 mmol) and indole (**1**) (113 mg, 0.964 mmol); a colorless oil; IR (neat) 2949, 1709, 1453, 1206, 1100, 837, 775, 749 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.47 (d, J = 8.4 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.52 (d, J = 4.2 Hz, 1H), 7.35 (dd, J = 8.4, 7.2 Hz, 1H), 7.27 (dd, J = 7.8, 7.2 Hz, 1H), 6.64 (d, J = 4.2 Hz, 1H), 3.76 (t, J = 6.0 Hz, 2H), 3.03 (t, J = 7.2 Hz, 2H), 2.06 (tt, J = 7.2, 6.0 Hz, 2H), 0.90 (s, 9H), 0.06 (s, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.6, 135.6, 130.4, 125.0, 124.8, 123.5, 120.8, 116.6, 109.0, 61.7, 32.2, 27.8, 25.9, 18.3, −5.4; HRMS Calcd for $C_{18}H_{28}NO_2Si$ [M^+ + H] 318.1889, found 318.1873.

*1-(1H-Indol-1-yl)pent-4-en-1-one (**10f**).* According to the general procedure described for **10a**, *N*-acylindole **10f** (93.4 mg, 0.469 mmol, 87%) was obtained from 4-pentenoic acid (**9f**) (54.0 mg, 0.537 mmol) and indole (**1**) (157 mg, 1.34 mmol); a colorless oil; IR (neat) 2953, 1708, 1453, 1387, 1363, 1320, 1307, 1206, 930, 767, 751 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.47 (d, J = 7.8 Hz, 1H), 7.56 (d, J = 8.4 Hz, 1H), 7.46 (d, J = 3.6 Hz, 1H), 7.35 (dd, J = 8.4, 7.2 Hz, 1H), 7.27 (dd, J = 7.8, 7.2 Hz, 1H), 6.64 (d, J = 3.6 Hz, 1H), 5.94 (dddd, J = 17.1, 10.2, 6.0, 6.0 Hz, 1H), 5.14 (d, J = 17.1 Hz, 1H), 5.07 (d, J = 10.2 Hz, 1H), 3.02 (t, J = 6.6 Hz, 2H), 2.62−2.58 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.7, 136.5, 135.6, 130.3, 125.1, 124.5, 123.6, 120.8, 116.6, 116.0, 109.1, 35.1, 28.4; HRMS Calcd for $C_{13}H_{14}NO$ [M^+ + H] 200.1075, found 200.1070. Spectroscopic date matched those previously reported.[12]

*1-(1H-Indol-1-yl)hex-5-yn-1-one (**10g**).* According to the general procedure described for **10a**, *N*-acylindole **10g** (67.3 mg, 0.319 mmol, 91%) was obtained from 5-hexynoic acid acid (**9g**) (39.0 mg, 0.350 mmol) and indole (**1**) (103 mg, 0.875 mmol); a white solid; mp 69−70 °C (hexanes-AcOEt); IR (neat) 2954, 1705, 1452, 1389, 1308, 1205, 752 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.46 (d, J = 8.4 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.50 (d, J = 3.6 Hz, 1H), 7.35 (dd, J = 8.4, 7.8 Hz, 1H), 7.27 (dd, J = 7.8, 7.8 Hz, 1H), 6.65 (d, J = 3.6 Hz, 1H), 3.08 (t, J = 7.2 Hz, 2H), 2.41 (dt, J = 7.2, 2.4 Hz, 2H), 2.07 (tt, J = 7.2, 7.2 Hz, 2H), 2.02 (t, J = 2.4 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.8, 135.6, 130.3, 125.1, 124.5, 123.6, 120.8, 116.6, 109.2, 83.2, 69.5, 34.2, 23.1, 17.8; HRMS Calcd for $C_{14}H_{14}NO$ [M^+ + H] 212.1075, found 212.1076.

*11-Bromo-1-(1H-indol-1-yl)undecan-1-one (**10h**).* According to the general procedure described for **10a**, *N*-acylindole **10h** (76.3 mg, 0.210 mmol, 71%) was obtained from 11-bromoundecanoic acid (**9h**) (79.0 mg, 0.297 mmol) and indole (**1**) (87.0 mg, 0.742 mmol); a white solid; mp 52−54 °C (hexanes-AcOEt); IR (neat) 2925, 2853, 1709, 1452, 1386, 1338, 1308, 1205, 767, 750 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.47 (d, J = 8.4 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.47 (d, J = 3.6 Hz, 1H), 7.35 (dd, J = 8.4, 6.6 Hz, 1H), 7.27 (dd, J = 7.8, 6.6 Hz, 1H), 6.64 (d, J = 3.6 Hz, 1H), 3.40 (t, J = 7.2 Hz, 2H), 2.91 (t, J = 7.2 Hz, 2H), 1.87−1.81 (m, 4H), 1.47−1.30 (m, 12H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.6, 135.6, 130.3, 125.1, 124.6, 123.5, 120.8, 116.6, 109.0, 35.9, 34.0, 32.8, 29.33, 29.31, 29.2, 28.7, 28.1, 24.6 (One signal is missing due to overlap); HRMS Calcd for $C_{19}H_{27}BrNO$ [M^+ + H] 364.1276, found 364.1272.

*(Z)-4-(2-((tert-Butyldimethylsilyl)oxy)ethyl)-1-(1H-indol-1-yl)hex-4-en-1-one (**10i**).* According to the general procedure described for **10a**, *N*-acylindole **10i** (105 mg, 0.281 mmol, 87%) was obtained from carboxylic acid **9i** (88.0 mg, 0.324 mmol) and indole (**1**) (95.0 mg, 0.810 mmol); a colorless oil; IR (neat) 2953, 1710, 1452, 1205, 835, 749 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.46 (d, J = 8.4 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.47 (d, J = 3.6 Hz, 1H), 7.35 (dd, J = 8.4, 7.2 Hz, 1H), 7.27 (dd, J = 7.8, 7.2 Hz, 1H), 6.64 (d, J = 3.6 Hz, 1H), 5.39 (q, J = 6.6 Hz, 1H), 3.67 (t, J = 7.8 Hz, 2H), 3.01 (t, J = 7.8 Hz, 2H), 2.54 (t, J = 7.8 Hz, 2H), 2.35 (t, J = 7.8 Hz, 2H), 1.62 (d, J = 6.6 Hz, 3H), 0.89 (s, 9H), 0.06 (s, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) 171.2, 135.6, 135.1, 130.3, 125.1, 124.6, 123.6, 121.8, 120.8, 116.6, 109.0, 61.8, 35.0, 33.8, 32.2, 25.9, 18.3, 13.5, −5.3; HRMS Calcd for $C_{22}H_{34}NO_2Si$ [M^+ + H] 372.2359, found 372.2350.

*1-(1H-Indol-1-yl)-4-phenylbutan-1-one (**10j**).* According to the general procedure described for **10a**, *N*-acylindole **10j** (112 mg, 0.426 mmol, 89%) was obtained from 4-phenylbutyric acid (**9j**) (79.0 mg, 0.478 mmol) and indole (**1**) (141 mg, 1.20 mmol); a white solid; mp 47−49 °C (hexanes-AcOEt); IR (neat) 2953, 1705, 1452, 1386, 1339, 1308, 1205, 767, 750, 700 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.46 (d, J = 7.8 Hz, 1H), 7.55 (d, J = 8.4 Hz, 1H), 7.37−7.29 (m, 4H), 7.26 (dd, J = 8.4, 7.8 Hz, 1H), 7.23−7.20 (m, 3H), 6.61 (d, J = 4.2 Hz, 1H), 2.90 (t, J = 7.2 Hz, 2H), 2.79 (t, J = 7.2 Hz, 2H), 2.19 (tt, J = 7.2, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.2, 141.2, 135.6, 130.3, 128.5, 126.1, 125.1, 124.5, 123.6, 120.8, 116.6, 109.0, 35.0, 34.8, 26.0 (One signal is missing due to overlap); HRMS Calcd for $C_{18}H_{18}NO$ [M^+ + H] 264.1388, found 264.1364.

*3-(2-Bromophenyl)-1-(1H-indol-1-yl)propan-1-one (**10k**).* According to the general procedure described for **10a**, *N*-acylindole **10k** (106 mg, 0.325 mmol, 87%) was obtained from 3-(2-bromophenyl)-propionic acid (**9k**) (86.0 mg, 0.376 mmol) and indole (**1**) (110 mg, 0.939 mmol); a white solid; mp 88−90 °C (hexanes-AcOEt); IR (neat) 2948, 1706, 1451, 1327, 1205, 767, 748 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.48 (d, J = 7.8 Hz, 1H), 7.51−7.55 (m, 2H), 7.46 (d, J = 3.6 Hz, 1H), 7.37−7.34 (m, 2H), 7.29−7.24 (m, 2H), 7.11 (dd, J = 7.8, 7.8 Hz, 1H), 6.62 (d, J = 3.6 Hz, 1H), 3.30−3.23 (m, 4H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.3, 139.6, 135.6, 133.0, 130.9, 130.3, 128.3, 127.8, 125.2, 124.5, 124.3, 123.7, 120.8, 116.6, 109.3, 35.9, 31.3; HRMS Calcd for $C_{17}H_{15}BrNO$ [M^+ + H] 328.0337, found 328.0316.

*3-(3-Bromophenyl)-1-(1H-indol-1-yl)propan-1-one (**10l**).* According to the general procedure described for **10a**, *N*-acylindole **10l** (87.5 mg, 0.268 mmol, 85%) was obtained from 3-(3-bromophenyl)-propionic acid (**9l**) (72.0 mg, 0.315 mmol) and indole (**1**) (92.0 mg, 0.785 mmol); a white solid; mp 59−61 °C (hexanes-AcOEt); IR (neat) 2953, 1707, 1452, 1326, 1205, 767, 751 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.46 (d, J = 7.8 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.44 (s, 1H), 7.42 (d, J = 4.2 Hz, 1H), 7.37−7.35 (m, 2H), 7.29−7.17 (m, 3H), 6.63 (d, J = 4.2 Hz, 1H), 3.22 (t, J = 7.8 Hz, 2H), 3.14 (t, J = 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.0, 142.7, 135.6, 131.5, 130.3, 130.2, 129.6, 127.2, 125.2, 124.3, 123.7, 122.6, 120.9, 116.6, 109.4, 37.3, 30.0; HRMS Calcd for $C_{17}H_{15}BrNO$ [M^+ + H] 328.0337, found 328.0320.

*4-(3-(1H-Indol-1-yl)-3-oxopropyl)benzonitrile (**10m**).* According to the general procedure described for **10a**, *N*-acylindole **10m** (70.8 mg, 0.258 mmol, 78%) was obtained from 3-(4-cyanophenyl)propionic acid (**9m**) (58.0 mg, 0.330 mmol) and indole (**1**) (97.0 mg, 0.828 mmol); a white solid; mp 121−122 °C (hexanes-AcOEt); IR (neat) 2953, 2226, 1705, 1452, 1389, 1328, 1206, 767, 752 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.46 (d, J = 7.8 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.44−7.42 (m, 4H), 7.29−7.17 (m, 3H), 6.63 (d, J = 4.2 Hz, 1H), 3.22 (t, J = 7.8 Hz, 2H), 3.14 (t, J = 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 169.7, 146.0, 135.6, 132.4, 130.3, 129.3, 125.3, 124.1, 123.8, 120.9, 118.8, 116.5, 110.4, 109.6, 36.7, 30.3; HRMS Calcd for $C_{18}H_{15}N_2O$ [M^+ + H] 275.1184, found 275.1170.

*1-(1H-Indol-1-yl)-3-(4-nitrophenyl)propan-1-one (**10n**).* According to the general procedure described for **10a**, *N*-acylindole **10n** (84.9 mg, 0.289 mmol, 76%) was obtained from 3-(4-nitrophenyl)propionic acid (**9n**) (75.0 mg, 0.387 mmol) and indole (**1**) (113 mg, 0.964 mmol); a white solid; mp 149−151 °C (hexanes-AcOEt); IR (neat) 2953, 1707, 1509, 1453, 1345, 1333, 1206, 1112, 752 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.44 (d, J = 7.8 Hz, 1H), 8.17 (d, J = 9.0 Hz, 2H), 7.56 (d, J = 7.8 Hz, 1H), 7.46 (d, J = 9.0 Hz, 2H), 7.42 (d, J = 3.6 Hz, 1H), 7.36 (dd, J = 7.8, 7.5 Hz, 1H), 7.28 (dd, J = 7.8, 7.5 Hz, 1H), 6.65 (d, J = 3.6 Hz, 1H), 3.29 (s, 4H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 169.6, 148.1, 146.7, 135.6, 130.3, 129.4, 125.3, 124.1, 123.9, 121.0, 116.5, 109.7, 36.6, 30.0 (One signal is missing due to overlap); HRMS Calcd for $C_{17}H_{15}N_2O_3$ [M^+ + H] 295.1083, found 295.1077.

*Methyl 4-(3-(1H-indol-1-yl)-3-oxopropyl)-3-nitrobenzoate (**10o**).* According to the general procedure described for **10a**, *N*-acylindole **10o** (81.4 mg, 0.231 mmol, 72%) was obtained from **9o** (81.0 mg, 0.321 mmol) and indole (**1**) (94.0 mg, 0.802 mmol); a white solid; mp 155−157 °C (hexanes-AcOEt); IR (neat) 2949, 1716, 1536, 1453, 1319, 1261, 764 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.62 (s, 1H), 8.44 (d, J = 7.8 Hz, 1H), 8.20 (d, J = 8.4 Hz, 1H), 7.65 (d, J = 8.4 Hz, 1H), 7.56 (d, J = 8.4 Hz, 1H), 7.44 (d, J = 3.6 Hz, 1H), 7.36 (dd, J = 8.1, 7.8 Hz, 1H), 7.28 (dd, J = 8.4, 8.1 Hz, 1H), 6.64 (d, J = 3.6 Hz,

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1H), 3.96 (s, 3H), 3.48 (t, J = 7.2 Hz, 2H), 3.37 (t, J = 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 169.6, 164.8, 149.3, 140.3, 135.6, 133.8, 133.1, 130.3, 130.2, 126.2, 125.3, 124.2, 123.8, 120.9, 116.5, 109.6, 52.7, 36.3, 28.3; HRMS Calcd for $C_{19}H_{16}N_2NaO_5$ [M + Na^+] 375.0957, found 375.0939.

*1-(1H-Indol-1-yl)-3-(6-nitrobenzo[d][1,3]dioxol-5-yl)propan-1-one (**10p**).* According to the general procedure described for **10a**, *N*-acylindole **10p** (103 mg, 0.302 mmol, 70%) was obtained from **9p** (103 mg, 0.431 mmol) and indole (**1**) (127 mg, 1.08 mmol); a white solid; mp 147−148 °C (hexanes-AcOEt); IR (neat) 2949, 1704, 1519, 1327, 1256, 1206, 1037, 752 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.46 (d, J = 8.4 Hz, 1H), 7.56 (d, J = 8.4 Hz, 1H), 7.54 (s, 1H), 7.48 (d, J = 3.6 Hz, 1H), 7.36 (dd, J = 8.4, 7.2 Hz, 1H), 7.27 (dd, J = 8.4, 7.2 Hz, 1H), 6.94 (s, 1H), 6.63 (d, J = 3.6 Hz, 1H), 6.09 (s, 2H), 3.38 (t, J = 7.2 Hz, 2H), 3.33 (t, J = 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.2, 152.0, 146.9, 142.8, 135.6, 133.0, 130.4, 125.2, 124.5, 123.7, 120.9, 116.6, 111.4, 109.4, 105.8, 102.9, 36.6, 29.2; HRMS Calcd for $C_{18}H_{15}N_2O_5$ [M^+ + H] 339.0981, found 339.0984.

*1-(1H-Indol-1-yl)-3-(thiophen-2-yl)propan-1-one (**10q**).* According to the general procedure described for **10a**, *N*-acylindole **10q** (51.3 mg, 0.201 mmol, 82%) was obtained from 3-(2-thienyl)propionic acid (**9q**) (38.0 mg, 0.244 mmol) and indole (**1**) (71.0 mg, 0.606 mmol); a white solid; mp 65−66 °C (hexanes-AcOEt); IR (neat) 2953, 1705, 1452, 1324, 1205, 767, 751, 698 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.47 (d, J = 7.8 Hz, 1H), 7.56 (d, J = 7.2 Hz, 1H), 7.43 (d, J = 3.0 Hz, 1H), 7.36 (dd, J = 7.8, 7.5 Hz, 1H), 7.27 (dd, J = 7.5, 7.2 Hz, 1H), 7.15 (d, J = 4.8 Hz, 1H), 6.93 (dd, J = 4.8, 4.2 Hz, 1H), 6.91 (d, J = 4.2 Hz, 1H), 6.63 (d, J = 3.0 Hz, 1H), 3.39 (t, J = 7.2 Hz, 2H), 3.29 (t, J = 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.0, 142.8, 135.6, 130.3, 127.0, 125.2, 125.0, 124.3, 123.7, 120.9, 116.6, 109.4, 37.8, 24.6 (One signal is missing due to overlap); HRMS Calcd for $C_{15}H_{14}NOS$ [M^+ + H] 256.0796, found 256.0785.

*1-(1H-Indol-1-yl)-2-(1,4-dioxaspiro[4.5]decan-8-yl)ethanone (**10r**).* According to the general procedure described for **10a**, *N*-acylindole **10r** (52.5 mg, 0.175 mmol, 56%) was obtained from **9r** (63.0 mg, 0.315 mmol) and indole (**1**) (92.0 mg, 0.788 mmol); a white solid; mp 96−98 °C (hexanes-AcOEt); IR (neat) 2953, 1704, 1452, 1317, 1204, 1105, 752 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.48 (d, J = 8.4 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.45 (d, J = 2.4 Hz, 1H), 7.35 (dd, J = 8.4, 7.8 Hz, 1H), 7.21 (dd, J = 7.8, 7.8 Hz, 1H), 6.63 (d, J = 2.4 Hz, 1H), 3.95 (s, 4H), 2.82 (d, J = 7.2 Hz, 2H), 2.15−2.08 (m, 1H), 1.90−1.88 (m, 2H), 1.78−1.76 (m, 2H), 1.65−1.59 (m, 2H), 1.45−1.39 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.7, 135.6, 130.4, 125.1, 124.7, 123.6, 120.8, 116.7, 109.0, 108.5, 64.3, 64.2, 42.2, 34.3, 33.3, 30.2; HRMS Calcd for $C_{18}H_{22}NO_3$ [M^+ + H] 300.1600, found 300.1579.

*Cyclopent-3-en-1-yl(1H-indol-1-yl)methanone (**10s**).* According to the general procedure described for **10a**, *N*-acylindole **10s** (46.7 mg, 0.221 mmol, 76%) was obtained from 3-cyclopentenecarboxylic acid (**9s**) (33.0 mg, 0.291 mmol) and indole (**1**) (85.0 mg, 0.725 mmol); a white solid; mp 76−77 °C (hexanes-AcOEt); IR (neat) 2953, 1700, 1451, 1360, 1339, 1309, 1289, 1224, 1206, 767, 750, 717 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.51 (d, J = 7.8 Hz, 1H), 7.57 (d, J = 7.2 Hz, 1H), 7.49 (d, J = 4.2 Hz, 1H), 7.35 (dd, J = 7.8, 7.5 Hz, 1H), 7.27 (dd, J = 7.5, 7.2 Hz, 1H), 6.65 (d, J = 4.2 Hz, 1H), 5.74 (s, 2H), 3.85 (tt, J = 9.6, 6.0 Hz, 1H), 2.93 (dd, J = 14.7, 6.0 Hz, 2H), 2.81 (dd, J = 14.7, 9.6 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 174.0, 135.9, 130.3, 128.8, 125.1, 124.7, 123.6, 120.7, 116.8, 109.1, 42.0, 36.9; HRMS Calcd for $C_{14}H_{14}NO$ [M^+ + H] 212.1075, found 212.1060.

*(S)-Benzyl 2-(1H-indole-1-carbonyl)pyrrolidine-1-carboxylate (**10t**).* According to the general procedure described for **10a**, *N*-acylindole **10t** (101 mg, 0.292 mmol, 72%, > 99% *ee*) was obtained from Cbz-L-proline **9t** (101 mg, 0.405 mmol) and indole (**1**) (118 mg, 1.01 mmol) in the presence of DMAP (10 mg, 0.082 mmol), and 2,6-lutidine (14 μL, 0.12 mmol); a white solid; mp 31−32 °C (hexanes-AcOEt); Enantiomeric excess was determined by HPLC analysis (CHIRALCEL OJ-H column, *n*-hexane-isopropanol (80:20 v/v as an eluent), 0.8 mL/min, λ = 254 nm, 25 °C, the retention times of (+)-isomer and (−)-isomer are 27 and 50 min, respectively); $[\alpha]_D^{26}$ − 109.3 (*c* 0.81, $CHCl_3$); IR (neat) 2954, 1700, 1452, 1415, 1355, 1308, 1204, 1123, 765, 751 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$, a mixture of two rotamers) δ 8.48−8.45 (m, 1H), 7.58−7.26 (m, 7H), 7.12−7.00 (m, 2H), 6.68−6.62 (m, 1H), 5.23−5.01 (m, 3H), 3.81−3.79 (m, 1H), 3.68−3.59 (m, 1H), 2.44−2.38 (m, 1H), 2.15−2.10 (m, 2H), 2.01−2.00 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$, a mixture of two rotamers) δ 170.7, 170.4, 155.0, 154.1, 136.6, 136.2, 135.94, 135.88, 128.5, 128.2, 128.0, 127.9, 127.7, 127.6, 125.4, 125.2, 124.0, 123.9, 123.6, 120.84, 120.80, 116.9, 116.8, 109.8, 67.23, 67.19, 59.5, 59.0, 47.2, 46.6, 31.4, 30.4, 24.3, 23.5; HRMS Calcd for $C_{21}H_{20}N_2NaO_3$ [M + Na^+] 371.1372, found 371.1354.

*(1H-Indol-1-yl)(phenyl)methanone (**10u**).* According to the general procedure described for **10a**, *N*-acylindole **10u** (31.0 mg, 0.140 mmol, 42%) was obtained from benzoic acid (**9u**) (41.0 mg, 0.337 mmol) and indole (**1**) (99.0 mg, 0.844 mmol) in the presence of DMAP (8.20 mg, 0.0674 mmol), and 2,6-lutidine (12 μL, 0.10 mmol); a white solid; mp 61−62 °C (hexanes-AcOEt); IR (neat) 2949, 1686, 1450, 1340, 1205, 887, 750, 700 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.40 (d, J = 7.8 Hz, 1H), 7.74 (d, J = 7.2 Hz, 2H), 7.65−7.60 (m, 2H), 7.53 (dd, J = 8.1, 7.2 Hz, 2H), 7.39 (dd, J = 8.1, 7.8 Hz, 1H), 7.33−7.30 (m, 2H), 6.62 (d, J = 3.6 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 168.7, 136.0, 134.6, 131.9, 130.8, 129.1, 128.6, 127.6, 124.9, 123.9, 120.9, 116.4, 108.5; HRMS Calcd for $C_{15}H_{12}NO$ [M^+ + H] 222.0919, found 222.0913. Spectroscopic date matched those previously reported.[3h]

*(1H-Indol-1-yl)(pyridin-2-yl)methanone (**10v**).* According to the general procedure described for **10a**, *N*-acylindole **10v** (73.3 mg, 0.330 mmol, 98%) was obtained from 2-pyridinecarboxylic acid (**9v**) (42.0 mg, 0.337 mmol) and indole (**1**) (99.0 mg, 0.844 mmol) in the presence of DMAP (8.20 mg, 0.0674 mmol), and 2,6-lutidine (12 μL, 0.10 mmol); a white solid; mp 79−81 °C (hexanes-AcOEt); IR (neat) 2949, 1684, 1539, 1451, 1437, 1382, 1347, 1205, 1193, 890, 767, 747, 698 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.74 (dd, J = 4.8, 1.2 Hz, 1H), 8.54 (d, J = 7.8 Hz, 1H), 8.09 (d, J = 7.2 Hz, 1H), 7.98 (d, J = 4.2 Hz, 1H), 7.94 (ddd, J = 7.5, 7.2, 1.2 Hz, 1H), 7.59 (d, J = 7.2 Hz, 1H), 7.51 (ddd, J = 7.5, 4.8, 1.2 Hz, 1H), 7.39 (dd, J = 7.8, 7.5 Hz, 1H), 7.32 (dd, J = 7.5, 7.2 Hz, 1H), 6.64 (d, J = 4.2 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 165.7, 152.4, 148.5, 137.4, 136.4, 130.7, 128.4, 126.1, 125.7, 124.9, 124.1, 120.7, 116.9, 109.1; HRMS Calcd for $C_{14}H_{11}N_2O$ [M^+ + H] 223.0871, found 223.0869. Spectroscopic date matched those previously reported.[3h]

*(1H-Indol-1-yl)(quinolin-2-yl)methanone (**10w**).* According to the general procedure described for **10a**, *N*-acylindole **10w** (78.3 mg, 0.288 mmol, 70%) was obtained from 2-quinolinecarboxylic acid (**9w**) (71.0 mg, 0.411 mmol) and indole (**1**) (121 mg, 1.03 mmol) in the presence of DMAP (10.0 mg, 0.0819 mmol), and 2,6-lutidine (14 μL, 0.12 mmol); a white solid; mp 125−127 °C (hexanes-AcOEt); IR (neat) 2953, 1684, 1451, 1383, 1349, 1206, 902, 825, 771, 761, 749 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.60 (d, J = 8.4 Hz, 1H), 8.39 (d, J = 8.4 Hz, 1H), 8.22 (d, J = 8.4 Hz, 1H), 8.16 (d, J = 4.2 Hz, 1H), 8.13 (d, J = 8.4 Hz, 1H), 7.94 (d, J = 8.4 Hz, 1H), 7.83 (dd, J = 8.4, 7.5 Hz, 1H), 7.70 (dd, J = 8.4, 7.5 Hz, 1H), 7.61 (d, J = 7.8 Hz, 1H), 7.41 (dd, J = 8.4, 7.2 Hz, 1H), 7.33 (d, J = 7.8, 7.2 Hz, 1H), 6.66 (d, J = 4.2 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 165.9, 151.9, 146.6, 137.5, 136.5, 130.8, 130.5, 130.3, 128.7, 128.6, 127.7, 125.0, 124.2, 121.6, 120.7, 117.0, 109.2 (One signal is missing due to overlap); HRMS Calcd for $C_{18}H_{13}N_2O$ [M^+ + H] 273.1028, found 273.1021.

*1-(6-Bromo-1H-indol-1-yl)-4-phenylbutan-1-one (**12a**).* According to the general procedure described for **10a**, *N*-acylindole **12a** (80.6 mg, 0.236 mmol, 88%) was obtained from 4-phenylbutyric acid (**9j**) (44.0 mg, 0.268 mmol) and 6-bromoindole (**11a**) (131 mg, 0.668 mmol); a white solid; mp 93−94 °C (hexanes-AcOEt); IR (neat) 2953, 1713, 1449, 1428, 1301, 1200, 886, 699 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.69 (s, 1H), 7.41−7.37 (m, 2H), 7.33−7.29 (m, 3H), 7.22−7.20 (m, 3H), 6.57 (d, J = 3.6 Hz, 1H), 2.88 (t, J = 7.8 Hz, 2H), 2.79 (t, J = 7.8 Hz, 2H), 2.18 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.1, 141.0, 136.2, 129.0, 128.53, 128.48, 126.9, 126.2, 124.9, 121.8, 119.7, 118.8, 108.7, 34.9, 34.7, 25.8; HRMS Calcd for $C_{18}H_{17}BrNO$ [M^+ + H] 342.0494, found 342.0474.

*1-(4-Phenylbutanoyl)-1H-indole-5-carbaldehyde (**12b**).* According to the general procedure described for **10a**, *N*-acylindole **12b** (65.5

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mg, 0.225 mmol, 84%) was obtained from 4-phenylbutyric acid (**9j**) (44.0 mg, 0.268 mmol) and indole-5-carbaldehyde (**11b**) (97.0 mg, 0.668 mmol); a white solid; mp 69−70 °C (hexanes-AcOEt); IR (neat) 2974, 1715, 1691, 1381, 1308, 1194, 1156, 700 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 10.1 (s, 1H), 8.60 (d, J = 7.8 Hz, 1H), 8.10 (s, 1H), 7.89 (d, J = 7.8 Hz, 1H), 7.47 (d, J = 3.6 Hz, 1H), 7.33−7.30 (m, 2H), 7.23−7.21 (m, 3H), 6.73 (d, J = 3.6 Hz, 1H), 2.93 (t, J = 7.2 Hz, 2H), 2.80 (t, J = 7.2 Hz, 2H), 2.20 (tt, J = 7.2, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.0, 171.3, 140.9, 139.0, 132.4, 130.5, 128.6, 128.5, 126.33, 126.29, 126.23, 123.6, 117.0, 109.4, 34.88, 34.85, 25.8; HRMS Calcd for $C_{19}H_{18}NO_2$ [M^+ + H] 292.1338, found 292.1320.

*1-(5-Nitro-1H-indol-1-yl)-4-phenylbutan-1-one (**12c**).* According to the general procedure described for **10a**, *N*-acylindole **12c** (77.3 mg, 0.251 mmol, 93%) was obtained from 4-phenylbutyric acid (**9j**) (45.0 mg, 0.271 mmol) and 5-nitroindole (**11c**) (110 mg, 0.678 mmol); a pale yellow solid; mp 89−90 °C (hexanes-AcOEt); IR (neat) 2974, 1717, 1518, 1339, 1308, 1198, 770, 742 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.58 (d, J = 8.4 Hz, 1H), 8.47 (s, 1H), 8.23 (d, J = 8.4 Hz, 1H), 7.53 (d, J = 3.6 Hz, 1H), 7.33−7.30 (m, 2H), 7.26−7.21 (m, 3H), 6.75 (d, J = 3.6 Hz, 1H), 2.94 (t, J = 7.2 Hz, 2H), 2.81 (t, J = 6.6 Hz, 2H), 2.21 (tt, J = 7.2, 6.6 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.3, 144.2, 140.8, 138.5, 130.1, 128.6, 128.5, 127.4, 126.3, 120.3, 117.0, 116.8, 109.4, 34.80, 34.77, 25.7; HRMS Calcd for $C_{18}H_{16}N_2NaO_3$ [M + Na^+] 331.1059, found 331.1032.

*1-(4-Phenylbutanoyl)-1H-indole-3-carbaldehyde (**12d**).* According to the general procedure described for **10a**, *N*-acylindole **12d** (97.8 mg, 0.336 mmol, 96%) was obtained from 4-phenylbutyric acid (**9j**) (57.0 mg, 0.350 mmol) and indole-3-carbaldehyde (**11d**) (127 mg, 0.875 mmol); a white solid; mp 87−88 °C (hexanes-AcOEt); IR (neat) 2973, 1727, 1676, 1550, 1447, 1187, 1126, 752, 700 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 10.1 (s, 1H), 8.41 (d, J = 8.4 Hz, 1H), 8.26 (d, J = 8.4 Hz, 1H), 7.94 (s, 1H), 7.44 (dd, J = 8.4, 7.8 Hz, 1H), 7.40 (dd, J = 8.4, 7.8 Hz, 1H), 7.34−7.31 (m, 2H), 7.26−7.22 (m, 3H), 2.97 (t, J = 7.8 Hz, 2H), 2.81 (t, J = 7.8 Hz, 2H), 2.22 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 185.6, 171.2, 140.7, 136.4, 134.5, 128.6, 128.5, 126.8, 126.4, 125.9, 125.3, 122.5, 121.9, 116.4, 34.7, 34.6, 25.7; HRMS Calcd for $C_{19}H_{18}NO_2$ [M^+ + H] 292.1338, found 292.1318.

*1-(3-Acetyl-1H-indol-1-yl)-4-phenylbutan-1-one (**12e**).* According to the general procedure described for **10a**, *N*-acylindole **12e** (92.6 mg, 0.303 mmol, 97%) was obtained from 4-phenylbutyric acid (**9j**) (51.0 mg, 0.313 mmol) and 3-acetylindole (**11e**) (125 mg, 0.785 mmol); a white solid; mp 101−103 °C (hexanes-AcOEt); IR (neat) 2949, 1718, 1665, 1545, 1448, 1388, 1197, 1148, 1016, 753 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.38 (d, J = 7.8 Hz, 1H), 8.33 (d, J = 7.2 Hz, 1H), 7.93 (s, 1H), 7.42−7.37 (m, 2H), 7.34−7.31 (m, 2H), 7.26−7.22 (m, 3H), 2.96 (t, J = 7.8 Hz, 2H), 2.82 (t, J = 7.8 Hz, 2H), 2.53 (s, 3H), 2.22 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 193.7, 171.3, 140.8, 136.0, 130.5, 128.6, 128.5, 127.1, 126.3, 126.2, 125.1, 122.4, 121.8, 116.2, 34.75, 34.71, 27.9, 25.8; HRMS Calcd for $C_{20}H_{20}NO_2$ [M^+ + H] 306.1494, found 306.1483.

*Ethyl 1-(4-phenylbutanoyl)-1H-indole-2-carboxylate (**12f**).* According to the general procedure described for **10a**, *N*-acylindole **12f** (101 mg, 0.300 mmol, 91%) was obtained from 4-phenylbutyric acid (**9j**) (54.0 mg, 0.330 mmol) and ethyl 1*H*-indole-2-carboxylate (**11f**) (156 mg, 0.824 mmol); a colorless oil; IR (neat) 2949, 1720, 1536, 1444, 1377, 1202, 747, 700 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.00 (d, J = 8.4 Hz, 1H), 7.62 (d, J = 8.4 Hz, 1H), 7.42 (dd, J = 8.4, 6.6 Hz, 1H), 7.31 (s, 1H), 7.28−7.23 (m, 3H), 7.18−7.12 (m, 3H), 4.34 (q, J = 7.8 Hz, 2H), 2.87 (t, J = 7.8 Hz, 2H), 2.66 (t, J = 7.8 Hz, 2H), 2.11 (tt, J = 7.8, 7.8 Hz, 2H), 1.37 (t, J = 7.8 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 174.3, 161.7, 141.2, 138.2, 129.5, 128.42, 128.39, 127.7, 127.2, 126.0, 123.5, 122.4, 117.6, 114.7, 61.6, 38.9, 35.0, 27.0, 14.2; HRMS Calcd for $C_{21}H_{21}NNaO_3$ [M + Na^+] 358.1419, found 358.1409.

*1-(2-Iodo-1H-indol-1-yl)-4-phenylbutan-1-one (**12g**).* According to the general procedure described for **10a**, *N*-acylindole **12g** (130 mg, 0.333 mmol, 90%) was obtained from 4-phenylbutyric acid (**9j**) (61.0 mg, 0.370 mmol) and 2-iodoindole (**11g**)[13] (225 mg, 0.926 mmol); a pale yellow solid; mp 49−50 °C (hexanes-AcOEt); IR (neat) 2949, 1711, 1438, 1259, 746 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.94 (d, J = 7.2 Hz, 1H), 7.46 (d, J = 7.2 Hz, 1H), 7.30−7.19 (m, 7H), 7.02 (s, 1H) 3.18 (t, J = 7.2 Hz, 2H), 2.77 (t, J = 7.8 Hz, 2H), 2.19 (tt, J = 7.8, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 141.1, 137.8, 131.1, 128.53, 128.48, 126.1, 124.7, 123.4, 123.2, 119.6, 114.8, 73.2, 39.2, 35.0, 26.9; HRMS Calcd for $C_{18}H_{16}INNaO$ [M + Na^+] 412.0174, found 412.0167.

*4-Phenyl-1-(2-phenyl-1H-indol-1-yl)butan-1-one (**12h**).* According to the general procedure described for **10a**, *N*-acylindole **12h** (35.3 mg, 0.104 mmol, 33%) was obtained from 4-phenylbutyric acid (**9j**) (52.0 mg, 0.320 mmol) and 2-phenylindole (**11h**) (154 mg, 0.798 mmol); a colorless oil; IR (neat) 2929, 1703, 1451, 1370, 1329, 1283, 1268, 1164, 749, 699 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.30 (d, J = 8.4 Hz, 1H), 7.55 (d, J = 7.2 Hz, 1H), 7.56−7.39 (m, 5H), 7.36−7.26 (m, 2H), 7.19−7.12 (m, 3H), 6.90 (d, J = 6.6 Hz, 2H), 6.60 (s, 1H), 2.38 (t, J = 7.8 Hz, 2H), 2.26 (t, J = 7.8 Hz, 2H), 1.87 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 174.7, 141.0, 139.4, 137.6, 134.2, 129.0, 128.71, 128.69, 128.5, 128.34, 128.28, 125.8, 125.0, 123.5, 120.4, 115.6, 111.3, 39.1, 34.8, 26.8; HRMS Calcd for $C_{24}H_{22}NO$ [M^+ + H] 340.1701, found 340.1683.

*1-(2-(4-((tert-Butyldiphenylsilyl)oxy)but-1-yn-1-yl)-1H-indol-1-yl)-4-phenylbutan-1-one (**12i**).* According to the general procedure described for **10a**, *N*-acylindole **12i** (234 mg, 0.411 mmol, 98%) was obtained from 4-phenylbutyric acid (**9j**) (69.0 mg, 0.418 mmol) and indole **11i** (440 mg, 1.04 mmol); a pale yellow solid; mp 73−75 °C (hexanes-AcOEt); IR (neat) 2950, 1707, 1449, 1284, 1110, 742, 701 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.43 (d, J = 8.4 Hz, 1H), 7.70−7.68 (m, 4H), 7.47−7.33 (m, 8H), 7.26−7.23 (m, 3H), 7.17−7.14 (m, 3H), 6.81 (s, 1H), 3.85 (t, J = 6.6 Hz, 2H), 3.22 (t, J = 7.2 Hz, 2H), 2.68−2.66 (m, 4H), 2.11 (tt, J = 7.2, 6.6 Hz, 2H), 1.08 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.3, 141.5, 136.5, 135.6, 133.4, 129.8, 128.6, 128.44, 128.37, 127.7, 125.99, 125.97, 123.8, 120.2, 119.7, 117.5, 117.0, 95.9, 74.7, 61.9, 37.3, 35.1, 26.8, 26.4, 24.0, 19.2; HRMS Calcd for $C_{38}H_{40}NO_2Si$ [M^+ + H] 570.2828, found 570.2785.

*1-(7-(Benzyloxy)-1H-indol-1-yl)-4-phenylbutan-1-one (**12j**).* According to the general procedure described for **10a**, *N*-acylindole **12j** (80.9 mg, 0.218 mmol, 93%) was obtained from 4-phenylbutyric acid (**9j**) (39.0 mg, 0.236 mmol) and 7-benzyloxyindole (**11j**) (132 mg, 0.592 mmol); a pale yellow solid; mp 42−43 °C (hexanes-AcOEt); IR (neat) 2953, 1726, 1704, 1583, 1485, 1421, 1300, 1260, 1247, 1196, 1070, 788, 742, 722, 697 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.54 (d, J = 3.6 Hz, 1H), 7.45 (d, J = 7.8 Hz, 2H), 7.38−7.31 (m, 3H), 7.25−7.14 (m, 5H), 7.56 (d, J = 7.2 Hz, 2H), 6.89 (d, J = 7.8 Hz, 1H), 6.57 (d, J = 3.6 Hz, 1H), 5.18 (s, 2H), 2.95 (t, J = 7.8 Hz, 2H), 2.53 (t, J = 7.8 Hz, 2H), 1.98 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.9, 147.2, 141.4, 136.5, 134.2, 128.6, 128.4, 128.3, 128.1, 127.7, 127.5, 125.9, 124.7, 124.0, 114.2, 108.0, 107.6, 71.1, 37.3, 34.9, 27.0; HRMS Calcd for $C_{25}H_{24}NO_2$ [M^+ + H] 370.1807, found 370.1798.

*Ethyl 1-(4-phenylbutanoyl)-1H-pyrrole-2-carboxylate (**12k**).* According to the general procedure described for **10a**, *N*-acylpyrrole **12k** (65.3 mg, 0.229 mmol, 68%) was obtained from 4-phenylbutyric acid (**9j**) (55.0 mg, 0.335 mmol) and ethyl pyrrole-2-carboxylate (**11k**) (117 mg, 0.841 mmol); a colorless oil; IR (neat) 2978, 1717, 1453, 1416, 1270, 1245, 1209, 1108, 756, 700 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.29−7.26 (m, 2H), 7.23 (dd, J = 2.4, 1.2 Hz, 1H), 7.21−7.17 (m, 3H), 6.93 (dd, J = 3.6, 1.2 Hz, 1H), 6.20 (dd, J = 3.6, 2.4 Hz, 1H), 4.29 (q, J = 7.8 Hz, 2H), 2.88 (t, J = 7.8 Hz, 2H), 2.71 (t, J = 7.8 Hz, 2H), 2.10 (tt, J = 7.8, 7.8 Hz, 2H), 1.34 (t, J = 7.8 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.2, 161.2, 141.1, 128.4, 126.1, 125.5, 125.2, 122.0, 110.8, 61.0, 36.2, 34.8, 26.4, 14.2 (One signal is missing due to overlap); HRMS Calcd for $C_{17}H_{19}NNaO_3$ [M + Na^+] 308.1263, found 308.1265.

*1-(2-Acetyl-1H-pyrrol-1-yl)-4-phenylbutan-1-one (**12l**).* According to the general procedure described for **10a**, *N*-acylpyrrole **12l** (60.0 mg, 0.235 mmol, 78%) was obtained from 4-phenylbutyric acid (**9j**) (49.0 mg, 0.300 mmol) and 2-acecyl pyrrole (**11l**) (81.0 mg, 0.750 mmol); a colorless oil; IR (neat) 2929, 1735, 1661, 1433, 1411, 1266, 747, 700 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.29−7.14 (m, 6H), 6.98 (dd, J = 3.4, 1.6 Hz, 1H), 6.22 (dd, J = 3.4, 2.8 Hz, 1H), 2.81 (t, J

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= 7.2 Hz, 2H), 2.69 (t, J = 7.6 Hz, 2H), 2.44 (s, 3H), 2.08 (tt, J = 7.6, 7.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.5, 174.1, 141.1, 133.7, 128.41, 128.36, 127.6, 126.0, 122.9, 110.5, 37.3, 34.8, 27.2, 26.6; HRMS Calcd for $C_{16}H_{17}NNaO_2$ [M + Na^+] 278.1157, found 278.1146.

*4-Phenyl-1-(1H-pyrazol-1-yl)butan-1-one (**12m**).* According to the general procedure described for **10a**, *N*-acylpyrazole **12m** (59.2 mg, 0.276 mmol, 85%) was obtained from 4-phenylbutyric acid (**9j**) (53.0 mg, 0.324 mmol) and pyrazole (**11m**) (55.0 mg, 0.808 mmol); a white solid; mp 34−35 °C (hexanes-AcOEt); IR (neat) 2978, 1735, 1415, 1344, 1200, 923, 745, 700 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.25 (d, J = 3.0 Hz, 1H), 7.69 (d, J = 1.8 Hz, 1H), 7.31−7.18 (m, 5H), 6.43 (dd, J = 3.0, 1.8 Hz, 1H), 3.17 (t, J = 7.8 Hz, 2H), 2.75 (t, J = 7.8 Hz, 2H), 2.13 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.0, 143.9, 141.3, 128.5, 128.4, 128.2, 126.0, 109.5, 35.1, 33.3, 25.9; HRMS Calcd for $C_{13}H_{14}N_2NaO$ [M + Na^+] 237.1004, found 237.0987.

*1-(9H-Carbazol-9-yl)-4-phenylbutan-1-one (**12n**).* According to the general procedure described for **10a**, *N*-acylcarbazole **12n** (85.3 mg, 0.272 mmol, 87%) was obtained from 4-phenylbutyric acid (**9j**) (51.0 mg, 0.313 mmol) and carbazole (**11n**) (131 mg, 0.783 mmol); a white solid; mp 87−88 °C (hexanes-AcOEt); IR (neat) 2949, 1696, 1445, 1375, 1283, 1210, 1156, 753, 721 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.14 (d, J = 7.8 Hz, 2H), 7.98 (d, J = 7.8 Hz, 2H), 7.44 (dd, J = 7.8, 7.5 Hz, 2H), 7.37 (dd, J = 7.8, 7.5 Hz, 2H), 7.31 (dd, J = 7.5, 7.2 Hz, 2H), 7.26−7.20 (m, 3H), 3.13 (t, J = 7.8 Hz, 2H), 2.84 (t, J = 7.8 Hz, 2H), 2.27 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 141.4, 138.5, 128.6, 128.5, 127.3, 126.4, 126.1, 123.5, 119.8, 116.4, 38.3, 35.1, 26.3; HRMS Calcd for $C_{22}H_{20}NO$ [M^+ + H] 314.1545, found 314.1534.

*1-(4-Phenylbutanoyl)pyrrolidin-2-one (**14a**).* According to the general procedure described for **10a**, imide **14a** (46.4 mg, 0.201 mmol, 64%) was obtained from 4-phenylbutyric acid (**9j**) (51.0 mg, 0.313 mmol) and 2-pyrrolidone (**13a**) (67.0 mg, 0.787 mmol); a white solid; mp 55−56 °C (hexanes-AcOEt); IR (neat) 2953, 1738, 1692, 1362, 1252, 747, 701 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.29−7.17 (m, 5H), 3.79 (t, J = 7.8 Hz, 2H), 2.94 (t, J = 7.8 Hz, 2H), 2.69 (t, J = 7.2 Hz, 2H), 2.58 (t, J = 8.4 Hz, 2H), 2.04−1.96 (m, 4H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.3, 174.1, 141.8, 128.5, 128.3, 125.8, 45.4, 36.3, 35.2, 33.7, 25.8, 17.2; HRMS Calcd for $C_{14}H_{17}NNaO_2$ [M + Na^+] 254.1157, found 254.1153.

*(S)-5-(((tert-Butyldimethylsilyl)oxy)methyl)-1-(4-phenylbutanoyl)-pyrrolidin-2-one (**14b**).* According to the general procedure described for **10a**, imide **14b** (68.1 mg, 0.181 mmol, 41%) was obtained from 4-phenylbutyric acid (**9j**) (72.0 mg, 0.440 mmol) and lactam **13b**[14] (252 mg, 1.10 mmol); pale yellow oil; $[\alpha]_D^{27}$ − 85.6 (*c* 1.00, $CHCl_3$); IR (neat) 2953, 1739, 1692, 1362, 1256, 1231, 1200, 1112, 837, 778 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.29−7.26 (m, 2H), 7.21−7.16 (m, 3H), 4.41−4.39 (m, 1H), 3.94 (dd, J = 10.5, 3.0 Hz, 1H), 3.65 (dd, J = 10.5, 2.4 Hz, 1H), 2.98−2.92 (m, 2H), 2.84−2.78 (m, 1H), 2.71−2.66 (m, 2H), 2.44−2.39 (m, 1H), 2.13−1.94 (m, 4H), 0.85 (s, 9H), 0.02 (s, 3H), −0.02 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 176.4, 174.0, 141.8, 128.5, 128.3, 125.8, 63.9, 58.0, 36.6, 35.3, 33.1, 25.9, 25.8, 21.2, 18.1, −5.6; HRMS Calcd for $C_{21}H_{33}NNaO_3Si$ [M + Na^+] 398.2127, found 398.2112.

*3-(4-Phenylbutanoyl)oxazolidin-2-one (**14c**).* According to the general procedure described for **10a**, imide **14c** (76.8 mg, 0.329 mmol, 91%) was obtained from 4-phenylbutyric acid (**9j**) (59.0 mg, 0.361 mmol) and 2-oxazolidone (**13c**) (79.0 mg, 0.907 mmol); a white solid; mp 79−80 °C (hexanes-AcOEt); IR (neat) 2949, 1770, 1698, 1393, 1113, 1038, 758, 702 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.29−7.17 (m, 5H), 4.38 (t, J = 7.8 Hz, 2H), 3.98 (t, J = 7.8 Hz, 2H), 2.96 (t, J = 7.2 Hz, 2H), 2.69 (t, J = 7.2 Hz, 2H), 2.01 (tt, J = 7.2, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.2, 153.5, 141.5, 128.5, 128.3, 125.9, 62.0, 42.5, 35.1, 34.5, 25.8; HRMS Calcd for $C_{13}H_{15}NNaO_3$ [M + Na^+] 256.0950, found 256.0945.

*(S)-4-Benzyl-3-(4-phenylbutanoyl)oxazolidin-2-one (**14d**).* According to the general procedure described for **10a**, imide **14d** (110 mg, 0.340 mmol, 98%) was obtained from 4-phenylbutyric acid (**9j**) (57.0 mg, 0.348 mmol) and (*S*)-4-benzyl-2-oxazolidinone (**13d**) (154 mg, 0.869 mmol). The reaction using equimolar amount of **13d** with Boc_2O (1.5 equiv) gave imide **14d** in 80% yield; a white solid; mp 78−80 °C (hexanes-AcOEt); $[\alpha]_D^{27}$ + 50.2 (*c* 1.00, $CHCl_3$); IR (neat) 2953, 1781, 1698, 1386, 1352, 1211, 744, 701 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.34−7.18 (m, 10H), 4.66−4.62 (m, 1H), 4.19−4.14 (m, 2H), 3.28 (dd, J = 13.5, 3.6 Hz, 1H), 3.03−2.93 (m, 2H), 2.77−2.71 (m, 3H), 2.04 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 153.4, 141.5, 135.3, 129.4, 128.9, 128.5, 128.4, 127.3, 126.0, 66.2, 55.1, 37.9, 35.1, 35.0, 25.8; HRMS Calcd for $C_{20}H_{21}NNaO_3$ [M + Na^+] 346.1419, found 346.1418.

*(S)-4-Isopropyl-3-(4-phenylbutanoyl)oxazolidin-2-one (**14e**).* According to the general procedure described for **10a**, imide **14e** (106 mg, 0.384 mmol, 99%) was obtained from 4-phenylbutyric acid (**9j**) (64.0 mg, 0.389 mmol) and (*S*)-4-isopropyl-2-oxazolidinone (**13e**) (125 mg, 0.968 mmol). The reaction using equimolar amount of **13e** with Boc_2O (1.5 equiv) gave imide **14e** in 85% yield; a white solid; mp 26−27 °C (hexanes-AcOEt); $[\alpha]_D^{28}$ + 68.1 (*c* 1.00, $CHCl_3$); IR (neat) 2946, 1781, 1701, 1387, 1206, 701 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.30−7.18 (m, 5H), 4.41 (ddd, J = 9.0, 7.5, 2.4 Hz, 1H), 4.25 (dd, J = 9.0, 9.0 Hz, 1H), 4.19 (dd, J = 9.0, 2.4 Hz, 1H), 3.04−2.99 (m, 1H), 2.95−2.90 (m, 1H), 2.69 (t, J = 7.2 Hz, 2H), 2.39−2.33 (m, 1H), 2.05−1.94 (m, 2H), 0.91 (d, J = 6.6 Hz, 3H), 0.87 (d, J = 6.6 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.0, 154.0, 141.5, 128.5, 128.3, 125.9, 63.3, 58.4, 35.1, 35.0, 28.4, 26.0, 18.0, 14.6; HRMS Calcd for $C_{16}H_{21}NNaO_3$ [M + Na^+] 298.1419, found 298.1412.

*N-Acetyl-N-4-diphenylbutanamide (**14f**).* According to the general procedure described for **10a**, imide **14f** (142 mg, 0.504 mmol, quant) was obtained from 4-phenylbutyric acid (**9j**) (83.0 mg, 0.504 mmol) and acetanilide (**13f**) (170 mg, 1.26 mmol); a colorless oil; IR (neat) 2937, 1707, 1491, 1366, 1236, 1121, 697 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46−7.39 (m, 3H), 7.27−7.24 (m, 2H), 7.19−7.09 (m, 5H), 2.61 (t, J = 7.2 Hz, 2H), 2.52 (t, J = 7.2 Hz, 2H), 2.31 (s, 3H), 1.94 (tt, J = 7.2, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.5, 173.0, 141.5, 139.1, 129.7, 128.8, 128.4, 128.3, 125.9, 37.7, 35.0, 27.0, 26.2 (One signal is missing due to overlap); HRMS Calcd for $C_{18}H_{19}NNaO_2$ [M + Na^+] 304.1313, found 304.1291.

*N-(2-Bromophenyl)-N-formyl-4-phenylbutanamide (**14g**).* According to the general procedure described for **10a**, imide **14g** (137 mg, 0.397 mmol, 94%) was obtained from 4-phenylbutyric acid (**9j**) (69.0 mg, 0.420 mmol) and 2-(bromophenyl)formamide (**13g**) (210 mg, 1.05 mmol); a white solid; mp 61−62 °C (hexanes-AcOEt); IR (neat) 2978, 1728, 1704, 1474, 1305, 1201, 1161, 751, 701 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 9.56 (s, 1H), 7.72 (dd, J = 7.8, 1.2 Hz, 1H), 7.42 (dd, J = 7.8, 6.0 Hz, 1H), 7.33 (ddd, J = 8.4, 7.8, 1.2 Hz, 1H), 7.27−7.24 (m, 2H), 7.18 (dd, J = 7.8, 7.8 Hz, 2H), 7.11 (d, J = 7.8 Hz, 2H), 2.66−2.57 (m, 2H), 2.21−2.20 (m, 2H), 2.00−1.94 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 174.4, 161.6, 141.0, 134.7, 133.9, 131.0, 130.6, 128.9, 128.41, 128.37, 126.1, 123.5, 34.9, 34.7, 25.3; HRMS Calcd for $C_{17}H_{16}BrNNaO_2$ [M^+ + H] 368.0262, found 368.0248.

*N-Acetyl-N-(2-bromophenyl)-4-phenylbutanamide (**14h**).* According to the general procedure described for **10a**, imide **14h** (142 mg, 0.396 mmol, 99%) was obtained from 4-phenylbutyric acid (**9j**) (66.0 mg, 0.400 mmol) and 2-bromoacetanilide (**13h**) (213 mg, 1.00 mmol); a white solid; mp 56−57 °C (hexanes-AcOEt); IR (neat) 2978, 1716, 1472, 1366, 1235, 1215, 1129, 756, 700 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.69 (dd, J = 8.1, 1.2 Hz, 1H), 7.41 (ddd, J = 8.4, 7.8, 1.2 Hz, 1H), 7.31−7.25 (m, 3H), 7.20−7.14 (m, 4H), 2.63 (t, J = 7.2 Hz, 2H), 2.54 (t, J = 7.8 Hz, 2H), 2.32 (s, 3H), 1.96 (tt, J = 7.8, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 174.7, 172.2, 141.5, 138.5, 133.7, 130.7, 130.4, 128.8, 128.4, 128.3, 125.9, 123.9, 37.4, 35.0, 26.7, 26.0; HRMS Calcd for $C_{18}H_{18}BrNNaO_2$ [M^+ + H] 382.0419, found 382.0408.

*N-(2-Bromophenyl)-N-(4-phenylbutanoyl)benzamide (**14i**).* According to the general procedure described for **10a**, imide **14i** (177 mg, 0.420 mmol, 95%) was obtained from 4-phenylbutyric acid (**9j**) (72.0 mg, 0.440 mmol) and 2-(bromophenyl)benzamide (**13i**) (302 mg, 1.10 mmol); a colorless oil; IR (neat) 2954, 1714, 1693, 1472, 1298, 699 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$, a mixture of two rotamers) δ 7.66−7.62 (m, 2H), 7.44−7.14 (m, 12H), 2.75−2.62 (m,

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4H), 2.08−2.02 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.8, 172.0, 141.5, 138.5, 135.2, 133.7, 131.8, 131.3, 130.0, 128.49, 128.46, 128.45, 128.36, 128.1, 125.9, 123.6, 37.1, 35.1, 26.4; HRMS Calcd for $C_{23}H_{20}BrNNaO_2$ [M^+ + H] 444.0575, found 444.0567.

*N-Acetyl-N-(2-methoxyphenyl)-4-phenylbutanamide (**14j**).* According to the general procedure described for **10a**, imide **14j** (97.4 mg, 0.313 mmol, 87%) was obtained from 4-phenylbutyric acid (**9j**) (59.0 mg, 0.359 mmol) and 2-acetanisidine (**13j**) (148 mg, 0.897 mmol); a pale yellow solid; mp 36−37 °C (hexanes-AcOEt); IR (neat) 2954, 1711, 1499, 1367, 1280, 1248, 1224, 1023, 753 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (dd, J = 7.5, 7.2 Hz, 1H), 7.25 (dd, J = 7.5, 7.2 Hz, 2H), 7.18−7.13 (m, 3H), 7.05 (d, J = 7.2 Hz, 1H), 7.01 (dd, J = 8.4, 7.5 Hz, 1H), 6.97 (d, J = 8.4 Hz, 1H), 3.78 (s, 3H), 2.61 (t, J = 7.2 Hz, 2H), 2.52 (br m, 2H), 2.30 (s, 3H), 1.93 (tt, J = 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.5, 173.0, 154.8, 141.7, 130.3, 130.0, 128.4, 128.3, 127.8, 125.8, 121.2, 111.9, 55.6, 37.0, 35.0, 26.5, 26.1; HRMS Calcd for $C_{19}H_{21}NNaO_3$ [M + Na^+] 334.1419, found 334.1424.

*N-Acetyl-N-(3-methoxyphenyl)-4-phenylbutanamide (**14k**).* According to the general procedure described for **10a**, imide **14k** (101 mg, 0.324 mmol, 94%) was obtained from 4-phenylbutyric acid (**9j**) (57.0 mg, 0.346 mmol) and 3-acetanisidine (**13k**) (143 mg, 0.866 mmol). The reaction using equimolar amount of **13k** with Boc_2O (1.5 equiv) gave imide **14k** in 81% yield; a colorless oil; IR (neat) 2954, 1709, 1604, 1489, 1367, 1292, 1212, 1030, 698 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.34 (dd, J = 8.4, 8.1 Hz, 1H), 7.27−7.25 (m, 2H), 7.19−7.13 (m, 3H), 6.95−6.94 (m, 1H), 6.70−6.68 (m, 1H), 6.63−6.62 (m, 1H), 3.80 (s, 3H), 2.61 (t, J = 7.8 Hz, 2H), 2.55 (t, J = 7.8 Hz, 2H), 2.33 (s, 3H), 1.94 (tt, J = 7.8, 7.8 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.5, 172.9, 160.6, 141.5, 140.1, 130.4, 128.4, 128.3, 125.9, 120.9, 114.6, 114.4, 55.4, 37.6, 35.0, 27.0, 26.2; HRMS Calcd for $C_{19}H_{21}NNaO_3$ [M + Na^+] 334.1419, found 334.1418.

*N-Acetyl-N-(3-(methylthio)phenyl)-4-phenylbutanamide (**14l**).* According to the general procedure described for **10a**, imide **14l** (112 mg, 0.342 mmol, 94%) was obtained from 4-phenylbutyric acid (**9j**) (60.0 mg, 0.365 mmol) and anilide **13l** (165 mg, 0.912 mmol). The reaction using equimolar amount of **13l** with Boc_2O (1.5 equiv) gave imide **14l** in 85% yield; a colorless oil; IR (neat) 2954, 1710, 1587, 1366, 1235, 1217, 1125, 698 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.35 (dd, J = 7.2, 7.2 Hz, 1H), 7.28−7.25 (m, 3H), 7.18 (dd, J = 7.2, 7.2 Hz, 1H), 7.13 (d, J = 6.6 Hz, 2H), 6.95 (dd, J = 2.4, 2.4 Hz, 1H), 6.85 (dd, J = 7.5, 2.4 Hz, 1H), 2.62 (t, J = 6.6 Hz, 2H), 2.52 (t, J = 7.8 Hz, 2H), 2.47 (s, 3H), 2.33 (s, 3H), 1.94 (tt, J = 7.8, 6.6 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.4, 172.9, 141.4, 140.8, 139.6, 129.9, 128.4, 128.3, 126.5, 126.3, 125.9, 125.2, 37.6, 34.9, 27.0, 26.2, 15.5; HRMS Calcd for $C_{19}H_{21}NNaO_2S$ [M + Na^+] 350.1191, found 350.1193.

*N-Acetyl-N-(4-methoxyphenyl)-4-phenylbutanamide (**14m**).* According to the general procedure described for **10a**, imide **14m** (79.5 mg, 0.256 mmol, 98%) was obtained from 4-phenylbutyric acid (**9j**) (43.0 mg, 0.260 mmol) and 4-acetanisidine (**13m**) (108 mg, 0.654 mmol); a colorless oil; IR (neat) 2954, 1708, 1509, 1366, 1248, 1219, 1028 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$, a mixture of two rotamers) δ 7.27−7.25 (m, 2H), 7.19−7.13 (m, 3H), 7.01−6.98 (m, 2H), 6.95−6.93 (m, 2H), 3.83 (s, 3H), 2.61 (t, J = 7.2 Hz, 2H), 2.52 (t, J = 7.8 Hz, 2H), 2.32 (s, 3H), 1.94 (tt, J = 7.8, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.8, 173.3, 159.6, 141.5, 131.6, 129.7, 128.4, 128.3, 125.9, 114.9, 55.4, 37.7, 35.0, 27.0, 26.2; HRMS Calcd for $C_{19}H_{21}NNaO_3$ [M + Na^+] 334.1419, found 334.1434.

*N-Acetyl-N-(2,6-dimethylphenyl)-4-phenylbutanamide (**14n**).* According to the general procedure described for **10a**, imide **14n** (122 mg, 0.395 mmol, 84%) was obtained from 4-phenylbutyric acid (**9j**) (77.0 mg, 0.467 mmol) and 2,6-dimethylacetanilide (**13n**) (191 mg, 1.17 mmol); a white solid; mp 29−30 °C (hexanes-AcOEt); IR (neat) 2954, 1708, 1367, 1254, 1224, 773, 700 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.27−7.12 (m, 8H), 2.62 (t, J = 7.2 Hz, 2H), 2.48 (t, J = 7.2 Hz, 2H), 2.27 (s, 3H), 2.09 (s, 6H), 1.95 (tt, J = 7.2, 7.2 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.1, 172.6, 141.5, 137.2, 135.6, 128.9, 128.8, 128.4, 128.3, 125.9, 36.9, 35.0, 26.3, 26.1, 17.8; HRMS Calcd for $C_{20}H_{23}NNaO_2$ [M + Na^+] 332.1626, found 332.1656.

*N-Acetyl-N-(naphthalen-1-yl)-4-phenylbutanamide (**14o**).* According to the general procedure described for **10a**, imide **14o** (120 mg, 0.362 mmol, 92%) was obtained from 4-phenylbutyric acid (**9j**) (65.0 mg, 0.394 mmol) and 1-acetamidonaphthalene (**13o**) (182 mg, 0.983 mmol). The reaction using equimolar amount of **13o** with Boc_2O (1.5 equiv) gave imide **14o** in 91% yield; a colorless oil; IR (neat) 2954, 1709, 1366, 1219, 776 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$, a mixture of two rotamers) δ 7.93−7.91 (m, 2H), 7.65−7.63 (m, 1H), 7.55−7.50 (m, 3H), 7.29 (d, J = 7.2 Hz, 1H), 7.23 (dd, J = 7.8, 7.2 Hz, 2H), 7.15 (dd, J = 7.8, 7.2 Hz, 1H), 7.08 (d, J = 7.8 Hz, 2H), 2.67−2.53 (m, 3H), 2.49−2.44 (m, 1H), 2.34 (s, 3H), 1.96−1.90 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.8, 173.2, 141.5, 135.5, 134.5, 130.5, 129.5, 128.7, 128.4, 128.3, 127.7, 126.9, 126.7, 125.9, 125.6, 121.5, 37.3, 34.9, 26.7, 26.2; HRMS Calcd for $C_{22}H_{21}NNaO_2$ [M + Na^+] 354.1470, found 354.1480.

*4-Phenyl-N-pivaloyl-N-(pyridin-2-yl)butanamide (**14p**).* According to the general procedure described for **10a**, imide **14p** (71.3 mg, 0.220 mmol, 54%) was obtained from 4-phenylbutyric acid (**9j**) (67.0 mg, 0.407 mmol) and 2-(pivaloylamino)pyridine (**13p**) (182 mg, 1.02 mmol); a colorless oil; IR (neat) 2954, 1698, 1588, 1466, 1434, 1280, 1140, 747, 700 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.41 (d, J = 4.8 Hz, 1H), 7.76 (ddd, J = 8.7, 7.2, 1.2 Hz, 1H), 7.36 (d, J = 7.2 Hz, 1H), 7.28−7.26 (m, 2H), 7.22−7.17 (m, 4H), 2.69 (t, J = 7.2 Hz, 2H), 2.51 (t, J = 7.2 Hz, 2H), 2.06 (tt, J = 7.2, 7.2 Hz, 2H), 1.10 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 186.5, 174.7, 152.0, 148.4, 141.5, 138.0, 128.5, 128.3, 125.9, 122.2, 121.8, 44.0, 35.7, 35.1, 28.4, 26.6; HRMS Calcd for $C_{20}H_{24}N_2NaO_2$ [M + Na^+] 347.1735, found 347.1726.

*Procedure for Multigram Scale Reaction. **Caution!** Because the reaction generates CO_2 gas, the multigram scale reaction should be conducted in flask equipped with balloon or under the open-air condition.*

*Methyl 4-(1H-indol-1-yl)-4-oxobutanoate (**10a**).* A 500 mL flask equipped with a magnetic stirring bar, was charged with Boc_2O (20.6 g, 94.6 mmol). A solution of *mono*-methyl succinate (**9a**) (5.00 g, 37.8 mmol), indole (**1**) (11.0 g, 94.6 mmol), DMAP (231 mg, 1.89 mmol), and 2,6-lutidine (440 μL, 3.78 mmol) in MeCN (83 mL) were added to the flask at room temperature. Then, the reaction mixture was warmed to 28 °C by water bath. After stirring at 28 °C for 24 h under argon atmosphere, the resulting mixture was concentrated under reduced pressure to give a crude oil, which was purified by silica gel column chromatography (AcOEt/hexanes = 1:5) to give *N*-acyl indole **10a** (8.46 g, 36.6 mmol, 97%).

*N-Acetyl-N-(naphthalen-1-yl)-4-phenylbutanamide (**14o**).* A 500 mL flask equipped with a magnetic stirring bar and argon balloon, was charged with Boc_2O (10.6 g, 48.6 mmol). A solution of 4-phenylbutyric acid (**9j**) (5.32 g, 32.4 mmol), 1-acetamidonaphthalene (**13o**) (6.00 g, 32.4 mmol), DMAP (200 mg, 1.64 mmol), and 2,6-lutidine (380 μL, 3.24 mmol) in MeCN (80 mL) were added to the flask at room temperature. Then, CH_2Cl_2 (100 mL) was added to a solution, and the reaction mixture was warmed to 28 °C by water bath. After stirring at 28 °C for 24 h under argon atmosphere, the resulting mixture was concentrated under reduced pressure to give a crude oil, which was purified by silica gel column chromatography (hexanes/AcOEt = 5:1) to give imide **14o** (10.1 g, 30.5 mmol, 94%).

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.6b02097.

Copies of ^{1}H and ^{13}C NMR spectra of compounds **10a**−**10w**, **12a**−**12n**, and **14a**−**14p**; Copy of HPLC chromatogram of **10t** (PDF)

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Notes

The authors declare no competing financial interest.

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