

## Catalyst-free Aqueous Multicomponent Domino Reactions from formaldehyde and 1,3-dicarbonyl derivatives

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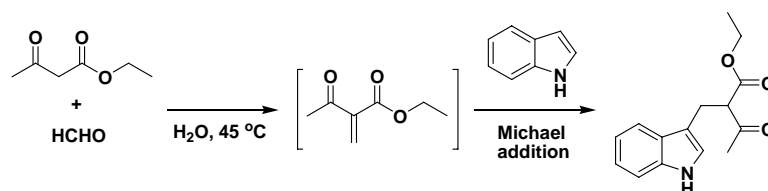
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### *Supporting Information*

#### **1) General remarks**

Silica gel (60 ACC 40-63  $\mu\text{m}$ , surface area: 550  $\text{m}^2/\text{g}$ ), heptane and ethyl acetate were purchased from CARLO ERBA REACTIFS-SDS. Formalin (37%, w/w), ethyl acetoacetate, 2,4-pentanedione, 4-methoxystyrene, 4-ethoxystyrene, 4-methylstyrene, 4-chlorostyrene,  $\alpha$ -methylstyrene, 1-methylindole, N-ethylaniline, ethyl benzoylacetate and chloroform-*d* were purchased from Aldrich Chemical Company. Benzoylacetone, benzyl acetoacetate, indene, indole, 1-methyl-2-phenylindole, 4-acetoxystyrene and 4-fluoro- $\alpha$ -methylstyrene were purchased from Acros Chemical Company. Styrene was purchased from TCI. Methyl acetoacetate, Butyl vinyl ether, 3,4-dihydropyran, 4-chloro- $\alpha$ -methylstyrene, paraformaldehyde, *tert*-butyl acetoacetate, 2-phenylindole and 4-*tert*-butylstyrene were purchased from Alfa Aesar Chemical Company.  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra were recorded on a Bruker Avance 300 DPX 300. Chemical shifts are expressed in ppm relative to  $\text{Me}_4\text{Si}$  in  $\text{CDCl}_3$ . IR spectra were recorded on a FT-IR Perkin Elmer (spectrum one) using ATR technology. Elemental analysis was measured on a NA 2100 Instrument. The reaction progress was monitored on a Varian 3300 GPC equipped with a BPX5 column (12m  $\times$  0.22 mm; phase thickness: 0.25  $\mu\text{m}$ ) supplied by SGE, a Flame Detector Ionization and an injector on column. Mass was recorded over a GC/MS HP5972. Melting points were recorded using a BüCHI B-540 Melting point apparatus.



**Scheme S1** Plausible reaction pathway for the three component reaction of indole, formaldehyde and ethyl acetoacetate.

## 2) Product characterizations (Note that copies of all NMR ( $^1\text{H}$ and $^{13}\text{C}$ ) spectra are provided at the end of this document)

**3-Acyl-2,6-dimethyl-6-phenyl-5,6-dihydropyran (3a):** Colorless liquid, 78% yield (Heptane/ethyl acetate: 2/1),  $^1\text{H}$  NMR: 1.55 (s, 3H), 1.85-2.08 (m, 2H), 2.11 (s, 3H), 2.15-2.33 (m, 2H), 2.37 (s, 3H), 7.19-7.27 (m, 3H), 7.32-7.36 (m, 2H);  $^{13}\text{C}$  NMR: 20.8, 21.3, 29.4, 29.5, 32.6, 79.3, 109.6, 124.2, 127.0, 128.5, 144.7, 163.2, 198.8. IR ( $\text{cm}^{-1}$ ): 2980, 2929, 2966, 1668, 1567, 1446, 1375, 1284, 1095, 1073, 945, 766, 699. HRMS (ESI): calcd for  $\text{C}_{15}\text{H}_{18}\text{O}_2$ ,  $[\text{M}]$  230.3022; found: 230.3109.

**2,6-Dimethyl-6-phenyl-3-(trifluoroacetyl)-5,6-dihydropyran (3b):** Colorless liquid, 82% yield (Heptane/ethyl acetate: 4/1),  $^1\text{H}$  NMR: 1.52 (s, 3H), 1.80-1.92 (m, 1H), 1.95-2.10 (m, 1H), 2.12-2.23(m, 1H), 2.36 (s, 3H), 7.12-7.22 (m, 3H), 7. 23-7.30 (m, 2H);  $^{13}\text{C}$  NMR: 18.2, 23.0, 29.9, 32.5, 81.7, 104.2, 111.6, 115.5, 119.4, 123.2, 124.4, 127.8, 129.1, 144.3, 172.7, 179.2, 179.6, 180.1, 180.5. IR ( $\text{cm}^{-1}$ ): 2979, 2929, 1689, 1548, 1384, 1331, 1296, 1273, 1198, 1132, 1062, 992, 924, 897, 842, 767, 736. HRMS (ESI): calcd for  $\text{C}_{15}\text{H}_{15}\text{F}_3\text{O}_2$ ,  $[\text{M}]$  = 284.2736; found: 284.2785.

**3-Benzoyl-2,6-dimethyl-6-phenyl-5,6-dihydropyran (3c):** Colorless liquid, 80% yield (Heptane/ethyl acetate: 4/1),  $^1\text{H}$  NMR: 1.52 (s, 3H), 1.79 (s, 3H), 1.83-1.90 (m, 2H), 2.17-2.40(m, 2H), 7.18-7.40 (m, 10H);  $^{13}\text{C}$  NMR: 21.2, 21.7, 30.2, 32.9, 79.9, 111.1, 124.9, 127.5, 128.7, 128.8, 129.0, 132.0, 159.9, 198.9. IR ( $\text{cm}^{-1}$ ): 3084, 3063, 3027, 2987, 2956, 2934, 2917, 2850, 1656, 1604, 1590, 1574, 1493, 1445, 1433, 1379, 1286, 1269, 1255, 1233, 1168, 1140, 1125, 1067, 1008, 919, 890, 803, 727, 696, 680. HRMS (ESI): calcd for  $\text{C}_{20}\text{H}_{20}\text{O}_2$ ,  $[\text{M} + \text{H}^+]$  = 293.3795; found: 293.3695.

**2,6-Dimethyl-3-methoxycarbonyl-6-phenyl-5,6-dihydropyran (3d):** Colorless liquid, 78% yield (Heptane/ethyl acetate: 4/1),  $^1\text{H}$  NMR: 1.47 (s, 3H), 1.75-1.91 (m, 2H), 2.05-2.29 (m, 2H), 2.32 (s, 3H), 3.56 (s, 3H), 7.12-7.28 (m, 5H);  $^{13}\text{C}$  NMR: 19.9, 20.9, 29.7, 32.8, 79.9, 101.3, 124.7, 127.4, 128.8, 145.3, 164.1, 169.2. IR ( $\text{cm}^{-1}$ ): 2978, 2948, 1706, 1621, 1446, 1434, 1379, 1296, 1278, 1264, 1233, 1186, 1165, 1094, 1086, 1073, 1028, 1012, 957, 762, 698. HRMS (ESI): calcd for  $\text{C}_{15}\text{H}_{18}\text{O}_3$ ,  $[\text{M} + \text{H}^+]$  = 247.3096; found: 247.3097.

**3-Ethoxycarbonyl-2,6-dimethyl-6-phenyl-5,6-dihydropyran (3e):** Colorless liquid, 77% yield (Heptane/ethyl acetate: 4/1),  $^1\text{H}$  NMR: 1.16 (t,  $J = 7.12$  Hz, 3H), 1.46 (s, 3H), 1.75-1.95 (m, 2H), 2.07-2.30 (m, 2H), 2.31 (s, 3H), 4.02 (quart-double,  $J_a = 7.15$  Hz,  $J_b = 2.82$  Hz, 2H), 7.12-7.29 (m, 5H);  $^{13}\text{C}$  NMR: 14.7, 19.9, 20.9, 29.7, 32.8, 59.9, 79.8, 101.5, 124.7, 127.3, 128.8, 145.4,

163.8, 168.8. IR (cm<sup>-1</sup>): 2977, 1703, 1622, 1263, 1071, 1028, 726, 699. HRMS (ESI): calcd for C<sub>16</sub>H<sub>20</sub>O<sub>3</sub>, [M + H<sup>+</sup>] = 261.3361; found: 261.3357.

**3-tert-Butoxycarbonyl-2,6-dimethyl-6-phenyl-5,6-dihydropyran (3f)**: Colorless liquid, 70% yield (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 1.44 (s, 9H), 1.52 (s, 3H), 1.78-1.97 (m, 2H), 2.09-2.31 (m, 2H), 2.36 (s, 3H), 7.18-7.37 (m, 5H); <sup>13</sup>C NMR: 20.2, 20.9, 28.8, 29.6, 33.0, 79.5, 79.6, 102.8, 124.8, 127.3, 128.8, 145.7, 162.6, 168.3. IR (cm<sup>-1</sup>): 2976, 2930, 1699, 1622, 1447, 1378, 1366, 1302, 1284, 1254, 1178, 1161, 1094, 1085, 1072, 1030, 1010, 989, 762, 698. HRMS (ESI): calcd for C<sub>18</sub>H<sub>24</sub>O<sub>3</sub>, [M] = 288.3814; found: 288.4819.

**3-Benzoxycarbonyl-2,6-dimethyl-6-phenyl-5,6-dihydropyran (3g)**: Colorless liquid, 81% yield (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 1.46 (s, 3H), 1.73-1.97 (m, 2H), 2.05-2.17 (m, 1H), 2.23-2.31 (m, 1H), 2.33 (s, 3H), 5.02 (dd, J<sub>a</sub> = 21.3 Hz, J<sub>b</sub> = 8.7 Hz, 2H), 7.13-7.30 (m, 10H); <sup>13</sup>C NMR: 19.9, 21.0, 29.7, 32.8, 65.9, 80.0, 101.2, 124.7, 127.4, 128.2, 128.9, 137.2, 145.3, 164.6, 168.5. IR (cm<sup>-1</sup>): 2978, 2931, 1072, 1622, 1446, 1378, 1276, 1262, 1231, 1165, 1085, 1071, 1029, 1012, 989, 762, 699. HRMS (ESI): calcd for C<sub>21</sub>H<sub>22</sub>O<sub>3</sub>, [M] = 322.3976; found: 322.3971.

**3-Ethoxycarbonyl-2,6-diphenyl-6-methyl-5,6-dihydropyran (3h)**: Colorless liquid, 64% yield (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 0.79 (t, J = 7.1 Hz, 3H), 1.53 (m, 3H), 1.80-1.99 (m, 1H), 2.05-2.26 (m, 2H), 2.37-2.52 (m, 1H), 3.79 (dd, J<sub>a</sub> = 14.2 Hz, J<sub>b</sub> = 7.1 Hz, 2H), 7.11-7.20 (m, 1H), 7.21-7.41 (m, 9H); <sup>13</sup>C NMR: 14.1, 20.8, 29.4, 32.8, 60.1, 80.5, 103.8, 124.9, 127.5, 128.2, 128.9, 129.0, 129.2, 137.9, 145.4, 162.3, 168.9. IR (cm<sup>-1</sup>): 2979, 2930, 1686, 1630, 1494, 1446, 1371, 1295, 1264, 1150, 1094, 1071, 1029, 759, 695. HRMS (ESI): calcd for C<sub>21</sub>H<sub>22</sub>O<sub>3</sub>, [M] = 322.3976; found: 322.3973.

**3-Acyl-2-methyl-6-phenyl-5,6-dihydropyran (3i)**:<sup>9(b)</sup> Colorless liquid, 54% yield (Heptane/ethyl acetate: 3/1), <sup>1</sup>H NMR: 1.75-1.92 (m, 1H), 2.03-2.16 (m, 1H), 2.17 (s, 3H), 2.23 (t, J = 1.4 Hz, 3H), 2.38-2.46 (m, 2H), 4.81 (dd, J<sub>a</sub> = 10.2 Hz, J<sub>b</sub> = 2.5 Hz, 1H), 7.22-7.37 (m, 5H); <sup>13</sup>C NMR: 20.1, 22.0, 28.3, 28.7, 76.9, 109.1, 124.8, 127.0, 127.5, 139.6, 163.6, 198.0. IR (cm<sup>-1</sup>): 2925, 2852, 1697, 1672, 1573, 1381, 1275, 1246, 1209, 1067, 1017, 937, 756, 699. HRMS (ESI): calcd for C<sub>14</sub>H<sub>16</sub>O<sub>2</sub>, [M] = 216.2756; found: 216.2777.

**3-Acyl-6-(4-chlorophenyl)-2,6-dimethyl-5,6-dihydropyran (3j)**: White solid, mp = 101-102 °C, 84% yield (Heptane/ethyl acetate: 2/1), <sup>1</sup>H NMR: 1.46 (s, 3H), 1.78-1.98 (m, 2H), 2.05 (s, 3H), 2.08-2.24 (m, 2H), 2.27 (s, 3H), 7.18 (dd, J<sub>a</sub> = 32.9 Hz, J<sub>b</sub> = 8.6 Hz, 4H); <sup>13</sup>C NMR: 21.0, 21.6, 29.7, 30.0, 32.9, 79.3, 110.0, 126.2, 129.1, 133.3, 143.7, 163.3, 199.2. IR (cm<sup>-1</sup>): 2983, 2931, 2844, 1669, 1566, 1490, 1375, 1254, 1111, 1089, 1043, 1008, 948, 899, 830, 794, 748, 723. HRMS (ESI): calcd for C<sub>15</sub>H<sub>17</sub>ClO<sub>2</sub>, [M] = 264.7473; found: 264.7479.

**3-Acyl-6-(4-chlorophenyl)-2-methyl-5,6-dihydropyran (3k)**: Colorless liquid, 28% yield (Heptane/ethyl acetate: 2/1), <sup>1</sup>H NMR: 1.70-1.88 (m, 1H), 2.02-2.12 (m, 1H), 2.16 (s, 3H), 2.21 (t, J = 1.4 Hz, 3H), 2.35-2.44 (m, 2H), 4.77 (dd, J<sub>a</sub> = 10.2 Hz, J<sub>b</sub> = 2.4 Hz, 1H), 7.15-7.30 (m, 4H); <sup>13</sup>C NMR: 21.4, 23.3, 29.7, 30.1, 77.6, 110.6, 127.6, 129.1, 134.1, 139.5, 164.6, 199.4. IR

(cm<sup>-1</sup>): 2948, 2925, 1673, 1580, 1567, 1492, 1384, 1358, 1274, 1244, 1208, 1075, 1013, 965, 936, 818, 789, 742, 669. HRMS (ESI): calcd for C<sub>14</sub>H<sub>15</sub>ClO<sub>2</sub>, [M] = 250.7207; found: 250.7211.

**3-Acyl-6-(4-fluorophenyl)-2,6-dimethyl-5,6-dihydropyran (3l)**: White solid, mp = 96-97 °C, 81 % yield, (Heptane/ethyl acetate: 2/1), <sup>1</sup>H NMR: 1.45 (s, 3H), 1.77-1.98 (m, 2H), 2.04 (s, 3H), 2.07-2.23 (m, 2H), 2.26 (s, 3H), 6.93 (t, J = 8.6 Hz, 2H), 7.12-7.22 (m, 2H); <sup>13</sup>C NMR: 21.1, 21.6, 29.7, 29.9, 33.0, 79.3, 110.0, 115.7 (d, J = 84.9 Hz, 2C), 126.4, (d, J = 32.1 Hz, 2C), 140.9 (d, J = 12.3 Hz, 1C), 160.5, 163.3, 163.8, 199.1. IR (cm<sup>-1</sup>): 2984, 2945, 2872, 1663, 1562, 1507, 1374, 1282, 1251, 1224, 1091, 1082, 1043, 1011, 946, 899, 814, 727, 656. HRMS (ESI): calcd for C<sub>15</sub>H<sub>17</sub>FO<sub>2</sub>, [M] = 248.2927; found: 248.2933.

**3-Acyl-6-(4-methoxyphenyl)-2-methyl-5,6-dihydropyran (3m)**: White solid, mp = 53 °C, 93% yield (Heptane/ethyl acetate: 2/1), <sup>1</sup>H NMR: 1.73-1.88 (m, 1H), 1.99-2.09 (m, 1H), 2.15 (s, 3H), 2.19 (t, J = 1.4 Hz, 3H), 2.35-2.43 (m, 2H), 3.71 (s, 3H), 4.72 (dd, J<sub>a</sub> = 10.4 Hz, J<sub>b</sub> = 2.3 Hz, 1H), 6.82 (dt, J<sub>a</sub> = 9.6 Hz, J<sub>b</sub> = 2.9 Hz, 2H), 7.18 (td, J<sub>a</sub> = 9.7 Hz, J<sub>b</sub> = 3.1 Hz, 2H); <sup>13</sup>C NMR: 21.6, 23.6, 29.6, 30.1, 78.2, 110.4, 114.2, 127.7, 133.0, 159.8, 165.2, 199.5. IR (cm<sup>-1</sup>): 2927, 2839, 1657, 1610, 1569, 1515, 1444, 1431, 1372, 1280, 1242, 1175, 1138, 1126, 1059, 1029, 1008, 936, 920, 875, 836, 817, 805, 762, 729, 697. HRMS (ESI): calcd for C<sub>15</sub>H<sub>18</sub>O<sub>3</sub>, [M] = 246.3016; found: 246.3112.

**3-Acyl-6-(4-ethoxyphenyl)-2-methyl-5,6-dihydropyran (3n)**: White solid, mp = 65-66 °C, 91% yield (Heptane/ethyl acetate: 3/2), <sup>1</sup>H NMR: 1.33 (t, J = 7.0 Hz, 3H), 1.74-1.92 (m, 1H), 2.00-2.11 (m, 1H), 2.15 (s, 3H), 2.19 (t, J = 1.4 Hz, 3H), 2.36-2.44 (m, 2H), 3.95 (dd, J<sub>a</sub> = 14.0 Hz, J<sub>b</sub> = 7.0 Hz, 2H), 4.73 (dd, J<sub>a</sub> = 10.3 Hz, J<sub>b</sub> = 2.3 Hz, 1H), 6.81 (dt, J<sub>a</sub> = 9.5 Hz, J<sub>b</sub> = 2.8 Hz, 2H), 7.16 (dt, J<sub>a</sub> = 9.5 Hz, J<sub>b</sub> = 2.7 Hz, 2H); <sup>13</sup>C NMR: 15.2, 21.6, 23.6, 29.6, 30.1, 63.8, 78.1, 110.4, 114.9, 127.6, 132.9, 159.1, 165.1, 199.4. IR (cm<sup>-1</sup>): 2992, 2981, 2936, 2913, 2882, 2846, 1663, 1616, 1568, 1516, 1479, 1365, 1243, 1214, 1173, 1117, 1068, 1047, 1009, 939, 921, 824, 809, 787, 727, 675. HRMS (ESI): calcd for C<sub>16</sub>H<sub>20</sub>O<sub>3</sub>, [M] = 260.3282; found: 260.3296.

**3-Acyl-2-methyl-6-(4-methylphenyl)-5,6-dihydropyran (3o)**: Colorless liquid, 71% yield (Heptane/ethyl acetate: 2/1), <sup>1</sup>H NMR: 1.74-1.90 (m, 1H), 2.05-2.16 (m, 1H), 2.15 (s, 3H), 2.20 (t, J = 1.4 Hz, 3H), 2.27 (s, 3H), 2.34-2.43 (m, 2H), 4.75 (dd, J<sub>a</sub> = 10.2 Hz, J<sub>b</sub> = 2.4 Hz, 1H), 7.04-7.19 (m, 4H); <sup>13</sup>C NMR: 21.6, 23.5, 29.7, 30.1, 78.3, 110.4, 126.2, 129.6, 138.0, 138.2, 165.1, 199.4. IR (cm<sup>-1</sup>): 2922, 2851, 1673, 1574, 1517, 1424, 1380, 1358, 1274, 1248, 1208, 1066, 1017, 935, 813, 772, 732, 672. HRMS (ESI): calcd for C<sub>15</sub>H<sub>18</sub>O<sub>2</sub>, [M] = 230.3022; found: 230.3029.

**3-Acyl-6-(4-tert-butylphenyl)-2-methyl-5,6-dihydropyran (3p)**: Colorless liquid, 67% yield (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 1.24 (s, 9H), 1.74-1.93 (m, 2H), 2.02-2.13 (m, 1H), 2.16 (s, 3H), 2.21 (t, J = 1.4 Hz, 3H), 2.35-2.44 (m, 2H), 4.77 (dd, J<sub>a</sub> = 10.3 Hz, J<sub>b</sub> = 2.4 Hz, 1H), 7.19 (dt, J<sub>a</sub> = 8.3 Hz, J<sub>b</sub> = 1.6 Hz, 2H), 7.33 (td, J<sub>a</sub> = 12.7 Hz, J<sub>b</sub> = 2.2 Hz, 2H); <sup>13</sup>C NMR: 20.1, 22.1, 28.1, 28.7, 30.3, 33.5, 76.9, 109.0, 124.4, 124.6, 136.5, 150.0, 163.7, 198.0. IR (cm<sup>-1</sup>): 2958, 2927, 2868, 1673, 1578, 1380, 1359, 1273, 1248, 1209, 1056, 1014, 936, 833, 705, 672. HRMS (ESI): calcd for C<sub>18</sub>H<sub>24</sub>O<sub>2</sub>, [M] = 272.3820; found: 272.3822.



**6-(4-Acetoxyphenyl)-3-Acyl-2-methyl-5,6-dihydropyran (3q):** Colorless liquid, 72 % yield (Heptane/ethyl acetate: 3/1), <sup>1</sup>H NMR: 1.73-1.88 (m, 1H), 2.05-2.15 (m, 1H), 2.17 (s, 3H), 2.21 (s, 3H), 2.24 (s, 3H), 2.37-2.48 (m, 2H), 4.80 (dd,  $J_a = 10.3$  Hz,  $J_b = 2.2$  Hz, 1H), 7.03 (d,  $J = 8.5$  Hz, 2H), 7.28 (d,  $J = 8.6$  Hz, 2H), <sup>13</sup>C NMR: 20.1, 20.1, 22.0, 28.3, 28.7, 76.4, 109.1, 120.7, 126.0, 137.1, 149.3, 163.4, 168.5, 198.0. IR (cm<sup>-1</sup>): 2926, 2959, 1756, 1672, 1579, 1567, 1508, 1420, 1361, 1275, 1191, 1165, 1076, 1015, 938, 911, 849, 819, 776, 743, 672. HRMS (ESI): calcd for C<sub>16</sub>H<sub>18</sub>O<sub>4</sub>, [M] = 274.3117; found: 274.3130.

**3-Acyl-2-methyl-4, 4a, 5, 9b-tetrahydroindeno[1,2-b]pyran (3s):** Colorless liquid, 79% yield (Heptane/ethyl acetate: 3/1), <sup>1</sup>H NMR: 2.12 (s, 3H), 2.16 (t,  $J = 1.4$  Hz, 3H), 2.54 (ddd,  $J_a = 16.0$  Hz,  $J_b = 6.2$  Hz,  $J_c = 1.1$  Hz, 1H), 2.65-2.76 (m, 2H), 2.95 (q,  $J = 8.4$  Hz, 1H), 5.24 (d,  $J = 5.4$  Hz, 1H), 7.12-7.23 (m, 3H), 7.34 (d,  $J = 6.8$  Hz, 1H), <sup>13</sup>C NMR: 21.6, 24.7, 30.1, 36.7, 36.9, 81.0, 108.8, 125.1, 125.9, 127.2, 129.3, 142.6, 142.8, 165.0, 199.4. IR (cm<sup>-1</sup>): 2915, 2846, 1670, 1613, 1573, 1462, 1439, 1376, 1355, 1309, 1216, 1133, 1101, 1076, 1041, 1017, 968, 931, 744. HRMS (ESI): calcd for C<sub>15</sub>H<sub>16</sub>O<sub>2</sub>, [M] = 228.2863; found: 228.3006.

**3-Acyl-2-methyl-6-phenyl-6-trimethylsiloxy-5,6-dihydropyran (3r):** Colorless liquid, yield: 40% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 0.00 (s, 9H), 1.64-1.80 (m, 1H), 2.07, 2.19 (m, 1H), 2.29 (s, 3H), 2.27-2.38 (m, 1H), 2.39 (s, 3H), 2.55-2.73 (m, 1H), 7.31-7.44 (m, 3H), 7.45-7.53 (dd,  $J_a = 8.1$  Hz,  $J_b = 1.7$  Hz, 2H); <sup>13</sup>C NMR: 0.0, 19.0, 19.9, 28.5, 34.8, 98.3, 109.8, 124.2, 126.9, 127.0, 143.2, 159.9, 198.0. IR (cm<sup>-1</sup>): 2960, 2927, 2899, 1678, 1622, 1581, 1497, 1359, 1277, 1264, 1247, 1161, 1080, 1064, 1014, 994, 954, 866, 842, 756, 704, 670, 659. HRMS (ESI): calcd for C<sub>17</sub>H<sub>24</sub>O<sub>3</sub>Si, [M + H<sup>+</sup>] = 305.4641; found: 305.1567.

**Ethyl  $\alpha$ -acetyl-1H-indole-3-propanoate (5a):**<sup>15(c)</sup> Colorless liquid, yield: 70% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 1.10 (t,  $J = 7.1$  Hz, 3H), 2.08 (s, 3H), 3.24 (d,  $J = 7.6$  Hz, 2H), 3.84 (t,  $J = 7.5$  Hz, 1H), 3.99-4.16 (m, 2H), 6.79 (t,  $J = 2.9$  Hz, 0.17 H), 6.84 (d,  $J = 2.2$  Hz, 0.83H), 6.96-7.17 (m, 2H), 7.50 (d,  $J = 7.9$  Hz, 1H), 8.0 (bs, 0.18H), 8.12 (bs, 0.88 H); <sup>13</sup>C NMR: 14.4, 24.3, 30.0, 60.6, 61.9, 111.7, 112.4, 118.9, 119.9, 122.5, 123.1, 127.4, 136.6, 170.1, 204.0.

**Methyl  $\alpha$ -acetyl-1H-indole-3-propanoate (5b):**<sup>15(e)</sup> Colorless liquid, yield: 64% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 2.08 (s, 3H), 3.25 (d,  $J = 7.7$  Hz, 2H), 3.60 (s, 3H), 3.86 (t,  $J = 7.5$  Hz, 1H), 6.86 (d,  $J = 2.3$  Hz, 1H), 7.00-7.17 (m, 2H), 7.23 (dd,  $J_a = 6.6$  Hz,  $J_b = 1.0$  Hz, 1H), 7.50 (d,  $J = 7.7$  Hz, 1H), 8.12 (bs, 1H); <sup>13</sup>C NMR: 22.9, 28.6, 51.4, 59.0, 110.3, 110.8, 117.4, 118.4, 121.1, 121.6, 125.9, 135.1, 169.0, 202.4.

**Ethyl  $\alpha$ -benzoyl-1H-indole-3-propanoate (5c):**<sup>15(d)</sup> Red liquid, yield: 54% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 1.02 (t,  $J = 7.1$  Hz, 3H), 3.42 (dd,  $J_a = 7.8$  Hz,  $J_b = 2.2$  Hz, 2H), 4.02 (ddd,  $J_a = 14.3$  Hz,  $J_b = 7.2$  Hz,  $J_c = 1.8$  Hz, 2H), 4.68 (t,  $J = 7.2$  Hz, 1H), 6.92 (d,  $J = 2.2$  Hz, 1H), 7.07 (quint/double,  $J_a = 7.0$  Hz,  $J_b = 1.2$  Hz, 2H), 7.24 (dd,  $J_a = 7.4$  Hz,  $J_b = 1.2$  Hz, 1H), 7.33 (t,  $J = 7.7$  Hz, 2H), 7.46 (t,  $J = 7.2$  Hz, 1H), 7.56 (d,  $J = 0.5$  Hz, 1H), 7.87 (dd,  $J_a = 7.5$  Hz,  $J_b = 1.4$  Hz, 2H), 8.0 (bs, 1H); <sup>13</sup>C NMR: 12.9, 23.6, 54.0, 60.4, 110.2, 111.4, 117.4, 118.4, 121.0, 121.9, 126.1, 127.6, 132.4, 135.1, 135.2, 168.7, 194.2. IR (cm<sup>-1</sup>

<sup>1</sup>): 3403, 3056, 2948, 2871, 1730, 1688, 1671, 1458, 1448, 1393, 1368, 1323, 1303, 1227, 1182, 1148, 1096, 1044, 967, 928, 911, 781, 740. HRMS (ESI): calcd for C<sub>20</sub>H<sub>19</sub>NO<sub>3</sub>, [M + H<sup>+</sup>] = 322.3777; found: 322.3794.

**Ethyl  $\alpha$ -acetyl-(1-methylindol-3-yl)-3-propanoate (5d)**: Colorless liquid, yield: 71% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 1.11 (t, J = 7.1 Hz, 3H), 2.08 (s, 3H), 3.22 (d, J = 7.5 Hz, 2H), 3.59 (s, 3H), 3.80 (t, J = 7.5 Hz, 1H), 4.06 (oktav, J = 7.1 Hz, 2H), 6.75 (s, 1H), 7.01 (t, J = 6.9 Hz, 1H), 7.07-7.20 (m, 2H), 7.48 (d, J = 7.9 Hz, 1H); <sup>13</sup>C NMR: 14.5, 24.2, 30.0, 33.0, 60.8, 61.8, 109.7, 111.0, 119.0, 119.4, 122.1, 127.8, 127.9, 137.3, 170.0, 203.7. IR (cm<sup>-1</sup>): 2980, 2933, 1737, 1713, 1473, 1357, 1325, 1219, 1198, 1146, 1013, 738. HRMS (ESI): calcd for C<sub>16</sub>H<sub>19</sub>NO<sub>3</sub>, [M + H<sup>+</sup>] = 274.3349; found: 274.3378.

**Methyl  $\alpha$ -acetyl-(1-methylindol-3-yl)-3-propanoate (5e)**: Colorless liquid, yield: 70% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 2.08 (s, 3H), 3.23 (d, J = 7.5 Hz, 2H), 3.60 (s, 6H), 3.82 (t, J = 7.5 Hz, 1H), 6.75 (s, 1H), 7.02 (td, J<sub>a</sub> = 6.8 Hz, J<sub>b</sub> = 1.4 Hz, 1H), 7.08-7.22 (m, 2H), 7.48 (d, J = 7.8 Hz, 1H); <sup>13</sup>C NMR: 22.8, 28.6, 31.6, 51.4, 59.2, 108.3, 109.5, 117.5, 117.9, 120.6, 126.3, 135.9, 168.9, 202.1. IR (cm<sup>-1</sup>): 2952, 1704, 1713, 1473, 1435, 1357, 1325, 1250, 1221, 1200, 1147, 1012, 738. HRMS (ESI): calcd for C<sub>15</sub>H<sub>17</sub>NO<sub>3</sub>, [M + H<sup>+</sup>] = 260.3083; found: 260.3091.

**tert-Butyl  $\alpha$ -acetyl-(1-methylindol-3-yl)-3-propanoate (5f)**: Colorless liquid, yield: 51% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 1.33 (s, 9H), 2.10 (s, 3H), 3.19 (dd, J<sub>a</sub> = 7.4 Hz, J<sub>b</sub> = 3.3 Hz, 2H), 3.63 (s, 3H), 3.73 (t, J = 7.5 Hz, 1H), 6.77 (s, 1H), 7.03 (td, J<sub>a</sub> = 7.9 Hz, J<sub>b</sub> = 1.2 Hz, 1H), 7.10-7.25 (m, 2H), 7.51 (d, J = 7.8 Hz, 1H); <sup>13</sup>C NMR: 22.5, 26.8, 28.4, 31.6, 60.3, 80.9, 108.2, 109.8, 117.7, 117.8, 120.6, 126.3, 126.5, 135.8, 168.0, 202.6. IR (cm<sup>-1</sup>): 2977, 2929, 1733, 1712, 1473, 1368, 1326, 1251, 1139, 844, 738. HRMS (ESI): calcd for C<sub>18</sub>H<sub>23</sub>NO<sub>3</sub>, [M + H<sup>+</sup>] = 302.3881; found: 302.3894.

**Ethyl  $\alpha$ -acetyl-(2-phenylindol-3-yl)-3-propanoate (5g)**: Red liquid, yield: 50% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 0.96 (t, J = 7.1 Hz, 3H), 1.91 (s, 3H), 3.43 (d, J = 7.5 Hz, 2H), 3.73-3.95 (m, 3H), 7.06 (quint, J = 8.0 Hz, 2H), 7.20 (d, J = 7.6 Hz, 1H), 7.26 (d, J = 7.1 Hz, 1H), 7.33 (t, J = 6.9 Hz, 2H), 7.43 (d, J = 7.0 Hz, 2H), 7.51 (d, J = 7.5 Hz, 1H), 8.17 (bs, 1H); <sup>13</sup>C NMR: 14.3, 23.7, 29.8, 60.2, 61.8, 109.1, 111.4, 119.4, 120.2, 122.8, 128.4, 128.6, 129.0, 129.4, 133.3, 135.8, 136.2, 170.0, 203.8. IR (cm<sup>-1</sup>): 3378, 2981, 1709, 1457, 1449, 1370, 1357, 1241, 1183, 1145, 1045, 911, 741, 698. HRMS (ESI): calcd for C<sub>21</sub>H<sub>21</sub>NO<sub>3</sub>, [M + H<sup>+</sup>] = 336.4043; found: 336.4055.

**Ethyl  $\alpha$ -acetyl-(1-methyl-2-phenylindol-3-yl)-3-propanoate (5h)**: Red liquid, yield: 52% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 0.99 (t, J = 7.1 Hz, 3H), 1.87 (s, 3H), 3.24 (ddd, J<sub>a</sub> = 22.0 Hz, J<sub>b</sub> = 14.7 Hz, J<sub>c</sub> = 7.4 Hz, 2H), 3.44 (s, 3H), 3.63 (t, J = 7.4 Hz, 1H), 3.82-3.99 (m, 2H), 7.05 (t, J = 7.8 Hz, 1H), 7.15 (t, J = 6.9 Hz, 1H), 7.22 (d, J = 8.1 Hz, 1H), 7.27 (s, 1H), 7.29 (d, J = 1.5 Hz, 1H), 7.33-7.47 (m, 3H), 7.53 (d, 7.8 Hz, 1H); <sup>13</sup>C NMR: 14.3, 23.8, 29.5, 31.2, 60.6, 61.6, 109.3, 109.9, 119.3, 119.9, 122.3, 127.7, 128.8, 129.0, 131.1, 132.1, 137.5, 139.1, 170.0, 203.5. IR (cm<sup>-1</sup>): 3053, 2979, 1738, 1713, 1468, 1443, 1364, 1331, 1240, 1209, 1146, 1015, 740, 703. HRMS (ESI): calcd for C<sub>22</sub>H<sub>23</sub>NO<sub>3</sub>, [M + H<sup>+</sup>] = 350.4309; found: 350.4352.

**3,4a-diacetyl-2,10a-dimethyl-10-ethyl-4,4a,5,10,10a-pentahydropyrano[2,3-b]quinoline (7a)**: Yellow pale liquid, yield: 77% (Heptane/ethyl acetate: 4/1), <sup>1</sup>H NMR: 1.15 (t, J = 7.4 Hz, 3H), 1.89 (s, 3H), 2.09 (s, 3H), 2.11 (s, 3H), 2.44 (dd, J<sub>a</sub> = 15.1 Hz,

$J_b = 7.5$  Hz, 2H), 2.81 (d,  $J = 15.8$  Hz, 1H), 3.20 (d,  $J = 15.8$  Hz, 1H), 3.54 (d,  $J = 12.5$  Hz, 1H), 3.87 (dd,  $J_a = 12.5$  Hz,  $J_b = 2.3$  Hz, 1H), 7.01 (d,  $J = 7.3$  Hz, 1H), 7.12-7.29 (m, 3H);  $^{13}\text{C}$  NMR: 13.3, 18.3, 22.1, 25.0, 25.5, 28.5, 29.3, 53.0, 64.4, 101.4, 126.4, 127.3, 128.3, 140.6, 141.9, 153.8, 194.6, 202.6, 202.7. IR ( $\text{cm}^{-1}$ ): 2977, 2876, 1698, 1636, 1516, 1489, 1357, 1233, 1146, 1119, 1046, 968, 943, 911, 775, 728, 683. HRMS (ESI): calcd for  $\text{C}_{20}\text{H}_{25}\text{NO}_3$ ,  $[\text{M} + \text{H}^+] = 328.4253$ ; found: 328.4255.

**3,4a-dimethoxycarbonyl-2,10a-dimethyl-10-ethyl-4,4a,5,10,10a-pentahydropyrano[2,3-b]quinoline (7b)**: Yellow pale liquid, yield: 47% (Heptane/ethyl acetate: 4/1),  $^1\text{H}$  NMR: 1.15 (td,  $J_a = 7.5$  Hz,  $J_b = 3.1$  Hz, 3H), 1.92 (d,  $J = 11.1$  Hz, 3H), 2.18 (d,  $J = 5.1$  Hz, 3H), 2.46 (ddd,  $J_a = 15.1$  Hz,  $J_b = 10.8$  Hz,  $J_c = 7.6$  Hz, 2H), 2.66 (d,  $J = 16.1$  Hz, 0.5 H), 2.87 (d,  $J = 16.2$  Hz, 0.5 H), 3.18 (ddd,  $J_a = 16.0$  Hz,  $J_b = 9.6$  Hz,  $J_c = 1.0$  Hz, 1H), 3.55 (d,  $J = 12.5$  Hz, 0.5 H), 3.58-3.75 (m, 1H), 3.63 (s, 3H), 3.65 (s, 1.5 H), 3.67 (s, 1.5 H), 3.84 (dd,  $J_a = 12.6$  Hz,  $J_b = 2.3$  Hz, 0.5 H), 6.84 (dd,  $J_a = 7.6$  Hz,  $J_b = 1.0$  Hz, 0.5 H), 7.02-7.28 (m, 3.5 H);  $^{13}\text{C}$  NMR: 13.3, 17.5, 17.6, 22.1, 22.4, 24.9, 25.3, 28.3, 28.5, 49.7, 51.7, 51.8, 52.7, 52.9, 56.4, 57.1, 90.5, 92.1, 125.8, 126.3, 126.9, 127.0, 127.4, 127.6, 128.0, 128.4, 140.7, 140.9, 142.2, 142.3, 153.3, 153.8, 167.6, 167.7, 169.5, 169.5. IR ( $\text{cm}^{-1}$ ): 2979, 2947, 2875, 1740, 1714, 1691, 1663, 1561, 1489, 1456, 1432, 1396, 1355, 1304, 1231, 1183, 1145, 1119, 1073, 1050, 968, 913, 775, 743. HRMS (ESI): calcd for  $\text{C}_{20}\text{H}_{25}\text{NO}_5$ ,  $[\text{M} + \text{H}^+] = 360.4241$ ; found: 360.4267.

