Metal-Free Visible-Light Induced Cyclization/Substitution Cascade Reaction of Alkyne-tethered Cyclohexadienones and Diselenides: Access to 5-Hydroxy-3-selenyl-4a,8a-dihydro-2H-chromen-6(5H)-ones

Xian-Li Ma,a† Qian Wang,a† Xi-Yuan Feng,b Zu-Yu Mo,b Ying-Ming Pan,b,* Yan-Yan Chen,a Mao Xin,a,* and Yan-Li Xu a,*

a Pharmacy School of Guilin Medical University, Guilin, 541004 People’s Republic of China.
b State Key Laboratory for the Chemistry and Molecular Engineering of Medicinal Resources, School of Chemistry and Pharmaceutical Sciences of Guangxi Normal University, Guilin 541004, People’s Republic of China.
† Xian-Li Ma and Qian Wang contributed equally to this work.
E-mail: panym@mailbox.gxnu.edu.cn; xinmao10225@163.com; yanli.xu@163.com
Fax and Tel.: (+86)-773-5846279

Table of Contents
General Information .................................................................................................................................................. S2
General Procedure for Synthesis of Alkyne-Tethered Cyclohexadienones 1 ......................................................... S2
General Procedure for Synthesis of Diphenyl Diselenides 2 ........................................................................... S3
General Procedure for the Synthesis of 3 and 5 ............................................................................................. S3
General Procedure for the Synthesis of 4 ......................................................................................................... S4
The X-ray Crystal Structure of 3b .................................................................................................................. S5
The X-ray Crystal Structure of 4b .................................................................................................................. S6
In vitro cytotoxicity ........................................................................................................................................... S7
Table 1. IC₅₀ values of products (3-4) towards four selected tumor cell lines and normal cell line for 48 h.a .......................... ........................................................................................................ S8
Analytical Data for All Compounds ............................................................................................................. S9
NMR Spectra for All Compounds ................................................................................................................ S24
HRMS Spectra for 6 and ¹⁸O-3a ..................................................................................................................... S59
General Information

Unless otherwise stated, all commercial reagents and solvents were used without additional purification. All the reactions were carried out under air atmosphere. $^1$H NMR and $^{13}$C NMR spectra were recorded in CDCl$_3$ at 400 MHz or 600 MHz, using CDCl$_3$ as a reference standard ($\delta = 7.26$ ppm) for $^1$H NMR and ($\delta = 77.00$ ppm) for $^{13}$C NMR. Melting points were measured with a micro melting point apparatus. TLC was performed using commercially prepared 100-400 mesh silica gel plates (GF$_{254}$), and visualization was effected at 254 nm. High resolution mass spectra (HRMS) were recorded on the Exactive Mass Spectrometer equipped with ESI ionization source.


A well-stirred solution of $p$-substituted phenol (1.0 mmol) in 1 mL of propargyl alcohol was added phenyliodine(III) diacetate (PIDA, 1.2 mmol) in several portions at 0 °C. The resulting reaction mixture was stirred at room temperature for overnight. Then the reaction mixture was diluted with water (5 mL) and extracted with ethyl acetate (5 mL $\times$ 3). The combined organic solvent was washed with brine (5 mL), dried (Na$_2$SO$_4$), filtered, and concentrated in vacuo. The crude reaction mixture was purified by column chromatography (EtOAc/hexane) to give the desired products S1.

To a solution of O-tethered alkyne S1 (3.0 mmol) in degassed Et$_3$N (3 mL) was added Pd(PPh$_3$)$_2$Cl$_2$ (3 mol %), CuI (1.5 mol %) and aryl iodide (3.6 mmol). The mixture was stirred at room temperature under a nitrogen atmosphere. The progress of the reaction was monitored by TLC. After the reaction was complete, quenched with water (10 mL), and the mixture was extracted with EtOAc (3 $\times$ 20 mL). The combined organic solvent was washed with 10% aqueous HCl to pH=7, dried (Na$_2$SO$_4$), filtered, and concentrated in vacuo. The mixture was purified by column chromatography (EtOAc/hexane) to give aryl substituted alkynes 1.

A well-stirred solution of $p$-methylphenol (1.0 mmol) in 1 mL of 2-butyne-1-ol was added phenyliodine(III)bis(trifluoroacetate) (PIFA, 1.2 mmol) in several portions at 0 °C. The resulting
reaction mixture was stirred at room temperature for overnight. Then the reaction mixture was
diluted with water (5 mL) and extracted with ethyl acetate (5 mL × 3). The combined organic solvent
was washed with brine (5 mL), dried (Na$_2$SO$_4$), filtered, and concentrated in vacuo. The crude
reaction mixture was purified by column chromatography (EtOAc/hexane) to give 4-(but-2-yn-1-
yloxy)-4-methylcyclohexa-2,5-dien-1-one 1r.

General Procedure for Synthesis of Diphenyl Diselenides 2.$^3$

To a stirred solution of magnesium (5.0 mmol) in dry THF (5 mL) and a single crystal of iodine
under a nitrogen atmosphere, was added bromobenzene (5.0 mmol) and the solution was heated
under a gentle reflux for 0.5 hours. The solution was allowed to cool to room temperature and
molecular selenium (5.0 mmol) was added in several portions. The resulting mixture was stirred for
30 minutes at room temperature and was quenched by the addition of 6 g ice. Concentrated
hydrochloric acid (1 mL) was added and the solution was extracted with diethyl ether (10 mL × 3).
The extract was diluted with 5 mL methanol and stirred overnight with O$_2$ balloon. The resulting
orange solution was dried over Na$_2$SO$_4$, evaporated under reduced pressure, and the residue was
purified by flash chromatography on a short silica gel column chromatography (EtOAc/hexane) to
give diphenyl diselenides 2.

General Procedure for the Synthesis of 3 and 5.
To a solution of alkyne-tethered cyclohexadienones 1 (0.3 mmol), diselenides 2 (0.3 mmol), \( \text{H}_2\text{O} \) (0.6 mmol), \( \text{CsOAc} \) (0.6 mmol), dry chlorobenzene (3 mL) was stirred at 40 °C under 25w white LEDs. The progress of the reaction was monitored by TLC. After the reaction was complete, quenched with water (3 mL), and the mixture was extracted with EtOAc (3 × 5 mL). The resulting orange solution was dried over Na\( _2\text{SO}_4 \), evaporated under reduced pressure, and the residue was purified by column chromatography (SiO\( _2 \), ethyl acetate/hexane gradient) yielding the desired products 3 or 5.

\textbf{Taking 3a as an example at 1 mmol scale:} To a solution of alkyne-tethered cyclohexadienone 1\( a \) (1.0 mmol), diselenides 2\( a \) (1.0 mmol), \( \text{H}_2\text{O} \) (2.0 mmol), \( \text{CsOAc} \) (2.0 mmol), dry chlorobenzene (10 mL). The mixture was stirred at 40 °C under 25w white LEDs. The progress of the reaction was monitored by TLC. After the reaction was complete, quenched with water (5 mL), and the mixture was extracted with EtOAc (3 × 10 mL). The resulting orange solution was dried over Na\( _2\text{SO}_4 \), evaporated under reduced pressure, and the residue was purified by column chromatography (SiO\( _2 \), ethyl acetate/hexane) yielding the desired products 3\( a \), 300.8 mg, 73% yield.

\textbf{General Procedure for the Synthesis of 4.}

To a solution of alkyne-tethered cyclohexadienones 1 (0.3 mmol), diphenyl diselenide 2 (0.6 mmol), dry toluene (3 mL). The mixture was stirred at 60 °C under 25w white LEDs. The progress of the reaction was monitored by TLC. After the reaction was complete, quenched with water (3 mL), and the mixture was extracted with EtOAc (3 × 5 mL). The resulting orange solution was dried over Na\( _2\text{SO}_4 \), evaporated under reduced pressure, and the residue was purified by column chromatography (SiO\( _2 \), ethyl acetate/hexane gradient) yielding the desired products 4.
The X-ray Crystal Structure of 3b.

![Chemical Structure of 3b](image)

**Bond precision:**  C-C = 0.0054 Å  \(\text{Wavelength}=0.71073\) Å

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cell:</strong></td>
<td>a=11.2346(8) b=13.8269(5) c=13.8545(8)</td>
</tr>
<tr>
<td></td>
<td>alpha=90 beta=112.472(7) gamma=90</td>
</tr>
<tr>
<td><strong>Temperature:</strong></td>
<td>100 K</td>
</tr>
<tr>
<td><strong>Volume:</strong></td>
<td>Calculated 1988.7(2)</td>
</tr>
<tr>
<td><strong>Space group:</strong></td>
<td>Reported 1988.7(2)</td>
</tr>
<tr>
<td><strong>Hall group:</strong></td>
<td>P 21/c</td>
</tr>
<tr>
<td><strong>Mol. formula:</strong></td>
<td>P 1 21/c 1</td>
</tr>
<tr>
<td><strong>Mol. formula:</strong></td>
<td>P 2ybc</td>
</tr>
<tr>
<td><strong>Sum formula:</strong></td>
<td>C23 H19 F3 O3 Se</td>
</tr>
<tr>
<td><strong>Sum formula:</strong></td>
<td>C23 H19 F3 O3 Se</td>
</tr>
<tr>
<td><strong>Mr:</strong></td>
<td>479.34</td>
</tr>
<tr>
<td><strong>Dx, g cm⁻³:</strong></td>
<td>479.34</td>
</tr>
<tr>
<td><strong>Dx, g cm⁻³:</strong></td>
<td>1.601</td>
</tr>
<tr>
<td><strong>Z:</strong></td>
<td>1.601</td>
</tr>
<tr>
<td><strong>Z:</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Mu (mm⁻¹):</strong></td>
<td>1.939</td>
</tr>
<tr>
<td><strong>Mu (mm⁻¹):</strong></td>
<td>1.939</td>
</tr>
<tr>
<td><strong>F000:</strong></td>
<td>968.0</td>
</tr>
<tr>
<td><strong>F000:</strong></td>
<td>968.0</td>
</tr>
<tr>
<td><strong>F000':</strong></td>
<td>968.17</td>
</tr>
<tr>
<td><strong>h,k,lmax:</strong></td>
<td>13,16,16</td>
</tr>
<tr>
<td><strong>Nref:</strong></td>
<td>3509</td>
</tr>
<tr>
<td><strong>Tmin,Tmax:</strong></td>
<td>0.792, 0.824</td>
</tr>
<tr>
<td><strong>Tmin':</strong></td>
<td>0.792</td>
</tr>
</tbody>
</table>

**Correction method:** #  Reported T Limits: Tmin=0.947 Tmax=1.000
**AbsCorr = MULTI-SCAN**

**Data completeness:** 1.000  \(\text{Theta(max)}=24.997\)

**R(reflections):** 0.0452 (2880)  \(\text{wR2(reflections)}=0.1063(3509)\)

**S = 1.054**  \(\text{Npar= 273}\)
The X-ray Crystal Structure of 4b.

<table>
<thead>
<tr>
<th>Bond precision:</th>
<th>C-C = 0.0079 Å</th>
<th>Wavelength=0.71073</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell:</td>
<td>a=14.2456(8)</td>
<td>b=11.4003(6)</td>
</tr>
<tr>
<td>Temperature:</td>
<td>100 K</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>2481.8(2)</td>
<td></td>
</tr>
<tr>
<td>Space group</td>
<td>P 21/n</td>
<td></td>
</tr>
<tr>
<td>Hall group</td>
<td>-P 2yn</td>
<td></td>
</tr>
<tr>
<td>Moiety formula</td>
<td>C29 F3 O2 Se2</td>
<td></td>
</tr>
<tr>
<td>Sum formula</td>
<td>C29 F3 O2 Se2</td>
<td></td>
</tr>
<tr>
<td>Mr</td>
<td>595.21</td>
<td></td>
</tr>
<tr>
<td>D, g cm⁻³</td>
<td>1.593</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Mu (mm⁻¹)</td>
<td>3.026</td>
<td></td>
</tr>
<tr>
<td>F000</td>
<td>1140.0</td>
<td></td>
</tr>
<tr>
<td>F000’</td>
<td>1139.88</td>
<td></td>
</tr>
<tr>
<td>h,k,lmax</td>
<td>16,13,18</td>
<td></td>
</tr>
<tr>
<td>Npar</td>
<td>4362</td>
<td></td>
</tr>
<tr>
<td>Tmin, Tmax</td>
<td>0.702, 0.785</td>
<td></td>
</tr>
<tr>
<td>Tmin’</td>
<td>0.689</td>
<td></td>
</tr>
</tbody>
</table>

Correction method= # Reported T Limits: Tmin=0.909 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 1.000
Theta(max) = 24.996
R(reflections)= 0.0495(3496)
wR2(reflections) = 0.1386(4362)
S = 1.064
Npar = 325
**In vitro cytotoxicity**

The T-24, MGC-803, HepG-2, SK-OV-3, WI-38 cell lines used in this study were all obtained from the Institute of Biochemistry and Cell Biology, China Academy of Sciences. All were supplemented with 10% heat-inactivated fetal bovine serum in a humidified atmosphere of 5% CO\(_2\)/95% air at 37 \(^\circ\)C. To investigate the potential of compounds 3-4, a commercial classical anticancer drug 5-fluorouracil (5-FU) was used as a reference organic drug. Assays of cytotoxicity were determined in 96-well, flat bottomed microtiter plates. The supplemented culture medium with cell lines was added to the wells. Compounds 3, 4 and 5-FU were dissolved in the culture medium with 1% DMSO to give various concentrations (2.5, 5, 10, 20, 40 \(\mu\)M, respectively). The resulted solutions were subsequently added to a set of wells. Control wells contained supplemented media with 1% DMSO. The microtiter plates were incubated at 37 \(^\circ\)C in a humidified atmosphere of 5% CO\(_2\)/95% air for a further 3 day. Cytotoxic screening by 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay was conducted. At the end of each incubation period, the MTT solution (10 mL, 5 mg/mL) was added into each well and the cultures were incubated further for 48 h (for the time-dependent cytotoxic effects studies, the treatment time is 24, 48, 72 h, respectively) at 37 \(^\circ\)C in a humidified atmosphere of 5% CO\(_2\)/95% air. After removal of the supernatant, DMSO (150 mL) was added to dissolve the formazan crystals. The absorbance was read by enzyme labeling instrument with 570/630 nm double wavelength measurement. The cytotoxicity was estimated based on the percentage cell survival in a dose dependent manner relative to the negative control. The final IC\(_{50}\) values were calculated by the Bliss method (n = 5). All the tests were repeated in at least three independent experiments.
Table 1. IC<sub>50</sub> values of products (3-4) towards four selected tumor cell lines and normal cell line for 48 h.<sup>a</sup>

<table>
<thead>
<tr>
<th>Compounds</th>
<th>T-24</th>
<th>MGC-803</th>
<th>HePG-2</th>
<th>SK-OV-3</th>
<th>WI-38</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3b</td>
<td>9.2 ± 1.8</td>
<td>5.7 ± 0.7</td>
<td>10.5 ± 1.1</td>
<td>12.2 ± 1.7</td>
<td>37.9 ± 1.6</td>
</tr>
<tr>
<td>3c</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3d</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3e</td>
<td>5.6 ± 0.9</td>
<td>5.0 ± 1.1</td>
<td>5.5 ± 0.9</td>
<td>8.6 ± 1.6</td>
<td>35.1 ± 1.9</td>
</tr>
<tr>
<td>3f</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3g</td>
<td>7.3 ± 1.4</td>
<td>9.5 ± 0.8</td>
<td>12.7 ± 1.1</td>
<td>18.4 ± 0.5</td>
<td>34.8 ± 0.8</td>
</tr>
<tr>
<td>3h</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3i</td>
<td>10.4 ± 0.8</td>
<td>6.1 ± 1.2</td>
<td>17.8 ± 2.3</td>
<td>20.1 ± 0.9</td>
<td>36.5 ± 1.2</td>
</tr>
<tr>
<td>3j</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3k</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3l</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3m</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3n</td>
<td>15.6 ± 0.6</td>
<td>14.7 ± 1.9</td>
<td>20.9 ± 0.7</td>
<td>25.3 ± 1.3</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3p</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3q</td>
<td>8.1 ± 0.4</td>
<td>7.2 ± 1.7</td>
<td>9.6 ± 0.8</td>
<td>10.1 ± 0.3</td>
<td>29.8 ± 0.7</td>
</tr>
<tr>
<td>3r</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3s</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3t</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3u</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>3v</td>
<td>13.9 ± 0.8</td>
<td>9.2 ± 1.3</td>
<td>12.1 ± 2.0</td>
<td>17.7 ± 0.7</td>
<td>33.2 ± 0.8</td>
</tr>
<tr>
<td>3w</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>4a</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>4b</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>4c</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>4d</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>4e</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>4f</td>
<td>14.7 ± 1.0</td>
<td>9.7 ± 1.5</td>
<td>17.9 ± 2.7</td>
<td>21.3 ± 2.5</td>
<td>&gt;40</td>
</tr>
<tr>
<td>4g</td>
<td>13.9 ± 0.5</td>
<td>10.0 ± 2.4</td>
<td>12.1 ± 1.8</td>
<td>19.0 ± 0.9</td>
<td>32.7 ± 0.4</td>
</tr>
<tr>
<td>4h</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>5-FU</td>
<td>35.2 ± 0.8</td>
<td>38.4 ± 1.1</td>
<td>&gt;40</td>
<td>&gt;40</td>
<td>&gt;40</td>
</tr>
</tbody>
</table>

<sup>a</sup>IC<sub>50</sub> values are presented as the mean ± SD (standard error of the mean) from three separated experiments.
Analytical Data for All Compounds.

(±)-5-Hydroxy-8a-methyl-4-phenyl-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3a). Pale yellow oil, 100.2 mg, 81% yield. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.49 (d, $J = 6.8$ Hz, 2H), 7.37 (t, $J = 7.5$ Hz, 2H), 7.29 (dt, $J = 10.7$, 7.2 Hz, 6H), 6.70 (d, $J = 10.0$ Hz, 1H), 6.12 (d, $J = 10.0$ Hz, 1H), 4.57 (d, $J = 10.9$ Hz, 1H), 4.37 (d, $J = 17.3$ Hz, 1H), 4.17 (d, $J = 17.3$ Hz, 1H), 3.19 (s, 1H), 2.82 (d, $J = 10.9$ Hz, 1H), 1.52 (s, 3H). $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 199.8, 150.9, 142.8, 139.9, 134.2, 129.4, 128.6, 128.1, 128.0, 128.0, 127.5, 126.2, 125.6, 77.4, 71.2, 67.2, 52.1, 23.0. HRMS ($m/z$) (ESI): calcd for C$_{22}$H$_{20}$NaO$_3$Se 435.0470 [M+Na]$^+$ found 435.0475.

(±)-5-Hydroxy-8a-methyl-3-(phenylselanyl)-4-(4-(trifluoromethyl)phenyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3b). Yellow solid, mp 138-140 ºC, 83.5 mg, 58% yield. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.59 (d, $J = 8.2$ Hz, 2H), 7.46 – 7.45 (m, 2H), 7.37 (d, $J = 8.2$ Hz, 2H), 7.31 – 7.27 (m, 3H), 6.71 (d, $J = 10.2$ Hz, 1H), 6.13 (d, $J = 10.2$ Hz, 1H), 4.56 (d, $J = 11.4$ Hz, 1H), 4.38 (d, $J = 17.5$ Hz, 1H), 4.21 (dd, $J = 17.5$, 1.6 Hz, 1H), 3.18 (d, $J = 2.4$ Hz, 1H), 2.76 (d, $J = 11.4$ Hz, 1H), 1.53 (s, 3H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 199.4, 150.6, 146.2, 138.7, 134.1, 129.4, 128.9, 128.1, 127.6, 127.0, 126.0, 124.9 (q, $J_{C-F} = 3.8$ Hz), 75.6, 71.0, 67.0, 51.9, 22.7. HRMS ($m/z$) (ESI): calcd for C$_{23}$H$_{20}$F$_3$NaO$_3$Se 503.0344 [M+Na]$^+$ found 503.0348.

(±)-4-(4-Ethylphenyl)-5-hydroxy-8a-methyl-3-(phenylselanyl)-4a,8a-
dihydro-2H-chromen-6(5H)-one (3c). Yellow solid, mp 218-220 °C, 116.2 mg, 88% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.51 – 7.46 (m, 2H), 7.29 – 7.25 (m, 3H), 7.19 (s, 4H), 6.69 (d, $J = 10.0$ Hz, 1H), 6.11 (d, $J = 10.0$ Hz, 1H), 4.56 (d, $J = 10.9$ Hz, 1H), 4.36 (d, $J = 17.2$ Hz, 1H), 4.17 (dd, $J = 17.2$, 1.6 Hz, 1H), 3.16 (d, $J = 2.0$ Hz, 1H), 2.81 (dd, $J = 10.9$, 1.2 Hz, 1H), 2.67 (q, $J = 7.6$ Hz, 2H), 1.52 (s, 3H), 1.26 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.7, 150.8, 143.2, 139.9, 139.7, 134.1, 129.2, 128.2, 128.1, 127.9, 127.4, 126.1, 125.1, 75.7, 71.1, 67.0, 52.1, 28.5, 22.8, 15.1. HRMS (m/z) (ESI): calcd for C$_{24}$H$_{24}$NaO$_3$Se 463.0783 [M+Na]$^+$ found 463.0785

![Image](image1.png)

(±)-5-Hydroxy-4-(4-methoxyphenyl)-8a-methyl-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3d). Yellow solid, mp 90-92 °C, 110.1 mg, 83% yield. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.49 (dd, $J = 7.8$, 1.4 Hz, 2H), 7.30 – 7.26 (m, 3H), 7.21 (d, $J = 8.6$ Hz, 2H), 6.90 (d, $J = 8.7$ Hz, 2H), 6.70 (d, $J = 10.0$ Hz, 1H), 6.12 (d, $J = 10.0$ Hz, 1H), 4.56 (d, $J = 10.9$ Hz, 1H), 4.35 (d, $J = 17.3$ Hz, 1H), 4.16 (dd, $J = 17.3$, 1.4 Hz, 1H), 3.82 (s, 3H), 3.21 (s, 1H), 2.79 (d, $J = 10.9$ Hz, 1H), 1.51 (s, 3H). $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 199.7, 158.7, 150.8, 139.4, 135.0, 134.0, 129.5, 129.2, 128.1, 127.9, 126.0, 125.1, 113.3, 75.7, 71.1, 67.0, 55.1, 52.1, 22.8. HRMS (m/z) (ESI): calcd for C$_{23}$H$_{22}$NaO$_4$Se 465.0576 [M+Na]$^+$ found 465.0578

![Image](image2.png)

(±)-4-[[1,1'-Biphenyl]-4-yl]-5-hydroxy-8a-methyl-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3e). Yellow oil, 114.2 mg, 78% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.64 – 7.57 (m, 4H), 7.53 – 7.48 (m, 2H), 7.43 (dd, $J = 10.4$, 4.8 Hz, 2H), 7.37 – 7.31 (m, 3H), 7.29 – 7.25 (m, 3H), 6.71 (d, $J = 10.0$ Hz, 1H), 6.13 (d, $J = 10.0$ Hz, 1H), 4.59 (d, $J = 10.9$, 2.6 Hz, 1H), 4.39 (d, $J = 17.3$ Hz, 1H), 4.20 (dd, $J = 17.3$, 1.6 Hz, 1H), 3.21 (d, $J = 2.6$ Hz, 1H), 2.85 (dd, $J = 10.9$, 1.0 Hz, 1H), 1.54 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.6, 150.7, 141.6, 140.7, 140.0, 139.4, 134.1, 129.3, 128.8, 128.7, 128.0, 127.9, 127.2, 127.1, 126.6, 126.1, 125.7,
75.7, 71.1, 67.1, 52.0, 22.8. HRMS (m/z) (ESI): calcd for C_{28}H_{24}NaO_{3}Se 511.0783 [M+Na]^+ found 511.0788.

(±)-4-(4-Chlorophenyl)-5-hydroxy-8a-methyl-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3f). Yellow solid, mp 156-158 °C, 105.7 mg, 79% yield. $^1$H NMR (600 MHz, CDCl$_3$) δ 7.47 – 7.46 (m, 2H), 7.33 – 7.26 (m, 5H), 7.20 (d, $J = 8.4$ Hz, 2H), 6.69 (d, $J = 10.0$ Hz, 1H), 6.12 (d, $J = 10.0$ Hz, 1H), 4.54 (d, $J = 11.0$ Hz, 1H), 4.35 (d, $J = 17.4$ Hz, 1H), 4.17 (dd, $J = 17.4$, 1.2 Hz, 1H), 3.21 (s, 1H), 2.73 (d, $J = 10.9$ Hz, 1H), 1.50 (s, 3H). $^{13}$C NMR (150 MHz, CDCl$_3$) δ 199.5, 150.6, 141.0, 138.7, 134.0, 133.1, 129.8, 129.3, 128.1, 128.0, 127.7, 126.3, 126.0, 75.6, 71.0, 67.0, 51.9, 22.7. HRMS (m/z) (ESI): calcd for C$_{22}$H$_{19}$ClNaO$_{3}$Se 469.0080 [M+Na]$^+$ found 469.0083.

(±)-4-(4-Bromophenyl)-5-hydroxy-8a-methyl-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3g). Yellow solid, mp 154-156 °C, 123.5 mg, 84% yield. $^1$H NMR (400 MHz, CDCl$_3$) δ 7.50 – 7.45 (m, 4H), 7.27 (dd, $J = 9.6$, 2.3 Hz, 3H), 7.17 – 7.12 (m, 2H), 6.69 (d, $J = 10.0$ Hz, 1H), 6.12 (d, $J = 10.0$ Hz, 1H), 4.54 (dd, $J = 11.0$, 1.9 Hz, 1H), 4.35 (d, $J = 17.4$ Hz, 1H), 4.17 (dd, $J = 17.4$, 1.6 Hz, 1H), 3.21 (s, 1H), 2.73 (dd, $J = 11.0$, 1.2 Hz, 1H), 1.50 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 199.5, 150.6, 141.5, 138.8, 134.1, 131.1, 130.2, 129.3, 128.1, 127.7, 126.3, 126.0, 121.3, 75.6, 71.0, 67.0, 51.9, 22.7. HRMS (m/z) (ESI): calcd for C$_{22}$H$_{19}$BrNaO$_{3}$Se 512.9575 [M+Na]$^+$ found 512.9576.

(±)-4-(5-Hydroxy-8a-methyl-6-oxo-3-(phenylselanyl)-4a,5,6,8a-

111
tetrahydro-2H-chromen-4-yl)benzaldehyde (3h). Yellow solid, mp 58-60 °C, 83.2 mg, 63% yield.

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 10.01 (s, 1H), 7.87 (d, \(J = 8.3\) Hz, 2H), 7.46 (ddd, \(J = 12.5, 6.8, 4.8\) Hz, 4H), 7.32 – 7.24 (m, 3H), 6.70 (d, \(J = 10.0\) Hz, 1H), 6.13 (d, \(J = 10.0\) Hz, 1H), 4.55 (dd, \(J = 11.0, 2.0\) Hz, 1H), 4.39 (d, \(J = 17.5\) Hz, 1H), 4.21 (dd, \(J = 17.5, 1.6\) Hz, 1H), 3.21 (d, \(J = 2.3\) Hz, 1H), 2.80 (dd, \(J = 11.0, 1.2\) Hz, 1H), 1.53 (s, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 199.3, 191.8, 150.5, 148.9, 138.9, 135.1, 134.1, 129.4, 129.3, 129.2, 128.2, 127.5, 127.2, 126.0, 75.5, 70.9, 67.0, 51.8, 22.7. HRMS (\(m/z\)) (ESI): calcd for C\(_{23}\)H\(_{20}\)NaO\(_4\)Se 463.0419 [M+Na]\(^+\) found 463.0417.

![Image](attachment:image1.png)

(±)-4-(4-Acetylphenyl)-5-hydroxy-8a-methyl-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3i). Yellow oil, 106.3 mg, 78% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.99 – 7.94 (m, 2H), 7.49 – 7.45 (m, 2H), 7.37 (d, \(J = 8.4\) Hz, 2H), 7.32 – 7.26 (m, 3H), 6.70 (d, \(J = 10.0\) Hz, 1H), 6.13 (d, \(J = 10.0\) Hz, 1H), 4.55 (dd, \(J = 11.0, 2.6\) Hz, 1H), 4.38 (d, \(J = 17.5\) Hz, 1H), 4.19 (dd, \(J = 17.5, 1.6\) Hz, 1H), 3.21 (d, \(J = 2.6\) Hz, 1H), 2.80 (dd, \(J = 11.0, 1.6\) Hz, 1H), 2.61 (s, 3H), 1.53 (s, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 199.4, 197.5, 150.6, 147.5, 139.0, 135.8, 134.1, 129.4, 128.8, 128.1, 128.0, 127.6, 126.8, 126.0, 75.6, 71.0, 67.0, 51.8, 26.6, 22.7. HRMS (\(m/z\)) (ESI): calcd for C\(_{24}\)H\(_{22}\)NaO\(_4\)Se 477.0576 [M+Na]\(^+\) found 477.0580.

![Image](attachment:image2.png)

(±)-Methyl 4-(5-hydroxy-8a-methyl-6-oxo-3-(phenylselanyl)-4a,5,6,8a-tetrahydro-2H-chromen-4-yl)benzoate (3j). Yellow solid, mp 49-51 °C, 102.9 mg, 73% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.03 (d, \(J = 8.4\) Hz, 2H), 7.50 – 7.44 (m, 2H), 7.37 – 7.26 (m, 5H), 6.70 (d, \(J = 10.0\) Hz, 1H), 6.12 (d, \(J = 10.0\) Hz, 1H), 4.55 (dd, \(J = 11.0, 1.2\) Hz, 1H), 4.38 (d, \(J = 17.5\) Hz, 1H), 4.19 (dd, \(J = 17.5, 1.9\) Hz, 1H), 3.91 (s, 3H), 3.18 (d, \(J = 1.9\) Hz, 1H), 2.79 (dd, \(J = 11.0, 1.2\) Hz, 1H), 1.52 (s, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 199.4, 166.8, 150.6, 147.3, 139.1, 134.1, 129.3, 129.2, 128.9, 128.6, 128.1, 127.6, 126.7, 126.0, 75.6, 71.0, 67.0, 52.0, 51.9, 22.7.
HRMS (m/z) (ESI): calcd for C_{24}H_{23}O_{5}Se 471.0705 [M+H]^+ found 471.0721.

(±)-5-Hydroxy-8a-methyl-4-(4-nitrophenyl)-3-(phenylselanyl)-4a,8a-dierydro-2H-chromen-6(5H)-one (3k). Yellow solid, mp 150-152 °C, 90.5 mg, 66% yield. \(^1\text{H NMR}\) (600 MHz, CDCl\textsubscript{3}) δ 8.24 (d, \(J = 8.7\) Hz, 2H), 7.50 – 7.45 (m, 4H), 7.36 – 7.32 (m, 3H), 6.75 (d, \(J = 10.0\) Hz, 1H), 6.18 (d, \(J = 10.0\) Hz, 1H), 4.59 (d, \(J = 11.0\) Hz, 1H), 4.43 (d, \(J = 17.7\) Hz, 1H), 4.26 (dd, \(J = 17.7, 1.5\) Hz, 1H), 2.80 (d, \(J = 11.0\) Hz, 1H), 1.57 (s, 1H). \(^{13}\text{C NMR}\) (150 MHz, CDCl\textsubscript{3}) δ 199.2, 150.4, 149.3, 146.7, 138.1, 134.1, 129.6, 129.5, 128.3, 128.0, 127.2, 126.0, 123.2, 75.5, 70.9, 66.9, 51.7, 22.7. HRMS (m/z) (ESI): calcd for C\textsubscript{22}H\textsubscript{19}NNaO\textsubscript{4}Se 480.0321 [M+Na]^+ found 480.0321.

(±)-5-Hydroxy-4-(3-methoxyphenyl)-8a-methyl-3-(phenylselanyl)-4a,8a-dierydro-2H-chromen-6(5H)-one (3l). Yellow solid, mp 87-89 °C, 95.5 mg, 72% yield. \(^1\text{H NMR}\) (400 MHz, CDCl\textsubscript{3}) δ 7.52 – 7.46 (m, 2H), 7.32 – 7.26 (m, 4H), 6.89 – 6.81 (m, 3H), 6.69 (d, \(J = 10.0\) Hz, 1H), 6.12 (d, \(J = 10.0\) Hz, 1H), 4.55 (dd, \(J = 10.9, 2.7\) Hz, 1H), 4.35 (d, \(J = 17.3\) Hz, 1H), 4.15 (dd, \(J = 17.3, 1.6\) Hz, 1H), 3.80 (s, 3H), 3.18 (d, \(J = 2.7\) Hz, 1H), 2.80 (dd, \(J = 10.9, 1.2\) Hz, 1H), 1.51 (s, 3H). \(^{13}\text{C NMR}\) (100 MHz, CDCl\textsubscript{3}) δ 199.6, 159.1, 150.7, 144.0, 139.2, 134.2, 129.2, 128.9, 128.0, 127.9, 126.1, 125.6, 120.8, 114.6, 112.4, 75.6, 71.1, 67.0, 55.2, 52.0, 22.8. HRMS (m/z) (ESI): calcd for C\textsubscript{23}H\textsubscript{21}NNaO\textsubscript{4}Se 465.0576 [M+Na]^+ found 465.0580.

(±)-3-(5-Hydroxy-8a-methyl-6-oxo-3-(phenylselanyl)-4a,5,6,8a-tetrahydro-2H-chromen-4-yl)benzonitrile (3m). Yellow solid, mp 60-62 °C, 85.2 mg, 65% yield. \(^1\text{H NMR}\) (400 MHz, CDCl\textsubscript{3}) δ 8.16 (d, \(J = 8.9\) Hz, 2H), 7.48 – 7.40 (m, 4H), 7.28 – 7.21 (m, 3H), 6.74 (d, \(J = 10.0\) Hz, 1H), 6.18 (d, \(J = 10.0\) Hz, 1H), 4.50 (d, \(J = 11.0\) Hz, 1H), 4.31 (d, \(J = 17.7\) Hz, 1H), 4.17 (dd, \(J = 17.7, 1.6\) Hz, 1H), 3.77 (s, 3H), 3.15 (d, \(J = 2.7\) Hz, 1H), 2.79 (dd, \(J = 10.9, 1.2\) Hz, 1H), 1.49 (s, 3H). \(^{13}\text{C NMR}\) (100 MHz, CDCl\textsubscript{3}) δ 199.5, 159.1, 150.5, 139.2, 134.2, 129.2, 128.9, 128.0, 127.9, 126.1, 125.6, 120.8, 114.6, 112.4, 75.6, 71.1, 67.0, 55.2, 52.0, 22.8. HRMS (m/z) (ESI): calcd for C\textsubscript{22}H\textsubscript{20}NNaO\textsubscript{3}Se 450.0565 [M+Na]^+ found 450.0576.
NMR (400 MHz, CDCl$_3$) $\delta$ 7.58 – 7.49 (m, 3H), 7.46 – 7.42 (m, 3H), 7.35 – 7.26 (m, 3H), 6.70 (d, $J = 10.0$ Hz, 1H), 6.13 (d, $J = 10.0$ Hz, 1H), 4.54 (dd, $J = 11.0$, 2.3 Hz, 1H), 4.37 (d, $J = 17.6$ Hz, 1H), 4.22 (dd, $J = 17.6$, 1.6 Hz, 1H), 3.19 (d, $J = 2.3$ Hz, 1H), 2.70 (dd, $J = 11.0$, 1.2 Hz, 1H), 1.52 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.2, 150.5, 143.81, 137.9, 134.2, 133.5, 132.3, 130.7, 129.4, 128.7, 128.3, 127.9, 127.3, 126.0, 118.8, 112.1, 75.6, 70.9, 67.0, 51.8, 22.7. HRMS ($m/z$) (ESI): calcd for C$_{23}$H$_{19}$NNaO$_3$Se 460.0422 [M+Na]$^+$ found 460.0424.

(±)-4-(3-Fluorophenyl)-5-hydroxy-8a-methyl-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3n). Yellow oil, 100.6 mg, 78% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.51 – 7.45 (m, 2H), 7.35 – 7.26 (m, 4H), 7.07 – 7.04 (m, 1H), 7.02 – 6.94 (m, 2H), 6.69 (d, $J = 10.0$ Hz, 1H), 6.12 (d, $J = 10.0$ Hz, 1H), 4.55 (dd, $J = 11.0$, 2.7 Hz, 1H), 4.35 (d, $J = 17.4$ Hz, 1H), 4.17 (dd, $J = 17.4$, 1.6 Hz, 1H), 3.19 (d, $J = 2.7$ Hz, 1H), 2.75 (dd, $J = 11.0$, 1.6 Hz, 1H), 1.51 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.5, 163.6, 161.2, 150.6, 144.7 (d, $J_{C-F} = 28$ Hz), 138.4, (d, $J_{C-F} = 8$ Hz), 134.3, 129.3, 128.1, 127.6, 126.5, 126.0, 124.3 (d, $J_{C-F} = 12$ Hz), 115.6 (d, $J_{C-F} = 88$ Hz), 114.2 (d, $J_{C-F} = 84$ Hz), 75.6, 71.0, 67.0, 52.0, 22.7. HRMS ($m/z$) (ESI): calcd for C$_{22}$H$_{19}$FNaO$_3$Se 453.0376 [M+Na]$^+$ found 453.0377.

(±)-5-Hydroxy-8a-methyl-3-(phenylselanyl)-4-(thiophen-2-yl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3p). Yellow solid, mp 170-172 °C, 80.3 mg, 64% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.55 (dd, $J = 7.8$, 1.6 Hz, 2H), 7.35 – 7.26 (m, 4H), 7.16 (dd, $J = 3.5$, 0.8 Hz, 1H), 7.04 (dd, $J = 5.1$, 3.7 Hz, 1H), 6.68 (d, $J = 10.0$ Hz, 1H), 6.13 (d, $J = 10.0$ Hz, 1H), 4.56 (dd, $J = 11.0$, 2.3 Hz, 1H), 4.34 (d, $J = 17.7$ Hz, 1H), 4.18 (dd, $J = 17.7$, 1.3 Hz, 1H), 3.28 (d, $J = 2.3$ Hz, 1H), 2.85 (d, $J = 11.0$ Hz, 1H), 1.47 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.6, 150.8, 143.9,
134.5, 131.6, 129.3, 128.2, 127.6, 127.4, 126.6, 126.2, 125.7, 75.6, 71.2, 67.4, 52.7, 22.7.

HRMS (m/z) (ESI): calcd for C_{20}H_{18}NaO_{3}SSe 441.0034 [M+Na]^+ found 441.0035.

![Chemical Structure](image)

\((\pm)-5\)-Hydroxy-8a-methyl-4-(naphthalen-2-yl)-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3q). Yellow oil, 98.4 mg, 71% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.85 – 7.79 (m, 3H), 7.64 (s, 1H), 7.50 – 7.44 (m, 5H), 7.29 – 7.25 (m, 3H), 6.72 (d, \(J = 10.0\) Hz, 1H), 6.13 (d, \(J = 10.0\) Hz, 1H), 4.61 (dd, \(J = 10.9, 2.8\) Hz, 1H), 4.41 (d, \(J = 17.3\) Hz, 1H), 4.22 (dd, \(J = 17.3, 1.2\) Hz, 1H), 3.13 (d, \(J = 2.8\) Hz, 1H), 2.93 (dd, \(J = 10.9, 1.2\) Hz, 1H), 1.59 (s, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 199.6, 150.7, 140.2, 139.6, 134.2, 133.0, 132.5, 129.2, 128.0, 127.9, 127.8, 127.7, 127.4, 127.1, 127.0, 126.1, 126.0, 126.0, 125.9, 76.7, 75.7, 71.2, 67.1, 52.3, 22.9.

HRMS (m/z) (ESI): calcd for C_{26}H_{22}NaO_{3}Se 485.0626 [M+Na]^+ found 485.0631.

![Chemical Structure](image)

\((\pm)-5\)-Hydroxy-4,8a-dimethyl-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3r). Yellow oil, 50.4 mg, 48% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.48 – 7.42 (m, 2H), 7.27 – 7.25 (m, 3H), 6.66 (d, \(J = 10.0\) Hz, 1H), 6.12 (d, \(J = 10.0\) Hz, 1H), 4.46 (dd, \(J = 11.2, 2.2\) Hz, 1H), 4.26 – 4.20 (m, 2H), 3.57 (d, \(J = 2.2\) Hz, 1H), 2.34 (d, \(J = 11.2\) Hz, 1H), 2.26 (t, \(J = 2.2\) Hz, 3H), 1.38 (s, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 200.1, 151.3, 138.9, 132.0, 129.4, 129.3, 127.1, 125.6, 121.4, 75.6, 71.0, 67.2, 51.0, 24.7, 22.7. HRMS (m/z) (ESI): calcd for C_{17}H_{18}NaO_{3}Se 373.0313 [M+Na]^+ found 373.0316.

![Chemical Structure](image)

\((\pm)-8a\)-Ethyl-5-hydroxy-4-phenyl-3-(phenylselanyl)-4a,8a-dihydro-2H-
chromen-6(5H)-one (3s). Yellow oil, 106.1 mg, 83% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.51 – 7.46 (m, 2H), 7.36 (dd, $J = 7.9$, 6.5 Hz, 2H), 7.32 – 7.25 (m, 6H), 6.75 (d, $J = 10.1$ Hz, 1H), 6.18 (d, $J = 10.1$ Hz, 1H), 4.61 (d, $J = 10.9$ Hz, 1H), 4.34 (d, $J = 17.3$ Hz, 1H), 4.17 (dd, $J = 17.3$, 1.6 Hz, 1H), 3.20 (s, 1H), 2.91 (dd, $J = 10.9$, 1.6 Hz, 1H), 1.98 – 1.80 (m, 2H), 0.98 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.6, 149.4, 142.7, 139.8, 134.0, 129.2, 128.5, 128.0, 127.9, 127.3, 127.3, 125.6, 75.9, 73.8, 67.2, 49.5, 27.4, 7.9. HRMS (m/z) (ESI): calcd for C$_{23}$H$_{22}$NaO$_3$Se 449.0626, [M+Na]$^+$ found 449.0632.

(±)-4,8a-Bis(4-bromophenyl)-5-hydroxy-3-(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (3t). Yellow solid, mp 113-115 °C, 143.6 mg, 76% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.61 (d, $J = 8.6$ Hz, 2H), 7.48 – 7.44 (m, 2H), 7.35 (d, $J = 8.6$ Hz, 2H), 7.19 – 7.11 (m, 3H), 7.04 (t, $J = 7.6$ Hz, 2H), 6.83 – 6.79 (m, 2H), 6.63 (d, $J = 9.9$ Hz, 1H), 6.10 (d, $J = 9.9$ Hz, 1H), 4.81 (dd, $J = 10.8$, 2.6 Hz, 1H), 4.53 (d, $J = 17.4$ Hz, 1H), 4.14 (dd, $J = 17.4$, 1.3 Hz, 1H), 3.57 (d, $J = 10.8$ Hz, 1H), 3.39 (d, $J = 2.6$ Hz, 1H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.2, 150.7, 141.2, 141.0, 139.8, 132.5, 132.3, 131.0, 130.2, 129.1, 128.6, 127.7, 127.3, 126.8, 125.3, 122.8, 121.7, 75.7, 75.6, 67.8, 49.1. HRMS (m/z) (ESI): calcd for C$_{27}$H$_{20}$Br$_2$NaO$_3$Se 654.8816, [M+Na]$^+$ found 654.8819.

(±)-5-Hydroxy-3-((4-methoxyphenyl)selanyl)-8a-methyl-4-phenyl-4a,8a-dihydro-2H-chromen-6(5H)-one (3u). Yellow solid, mp 55-57 °C, 114.1 mg, 86% yield. $^1$H NMR
(400 MHz, CDCl$_3$) $\delta$ 7.45 – 7.42 (m, 2H), 7.38 (t, $J = 7.3$ Hz, 2H), 7.33 – 7.27 (m, 3H), 6.82 – 6.78 (m, 2H), 6.68 (d, $J = 10.0$ Hz, 1H), 6.10 (d, $J = 10.0$ Hz, 1H), 4.53 (d, $J = 10.9$ Hz, 1H), 4.29 (d, $J = 17.2$ Hz, 1H), 4.09 (dd, $J = 17.2$, 1.6 Hz, 1H), 3.80 (s, 3H), 3.14 (s, 1H), 2.76 (dd, $J = 10.9$, 1.1 Hz, 1H), 1.49 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.7, 160.0, 150.7, 142.6, 137.2, 137.0, 128.5, 127.9, 127.3, 126.3, 126.0, 117.0, 114.8, 75.6, 71.0, 66.8, 55.3, 51.9, 22.7. HRMS ($m/z$) (ESI): calcd for $^{23}$H$_{22}$NaO$_4$Se 465.0576 [M+Na]$^+$ found 465.0579.

(±)-3-((3-Fluorophenyl)selanyl)-5-hydroxy-8a-methyl-4-phenyl-4a,8a-dihydro-2H-chromen-6(5H)-one (3v). Yellow oil, 51.6 mg, 40% yield. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.30 – 7.22 (m, 4H), 7.18 – 7.16 (m, 4H), 7.10 – 7.09 (m, 1H), 6.64 (d, $J = 10.0$ Hz, 1H), 6.06 (d, $J = 10.0$ Hz, 1H), 4.50 (dd, $J = 10.9$, 2.6 Hz, 1H), 4.32 (d, $J = 17.3$ Hz, 1H), 4.15 (dd, $J = 17.3$, 1.6 Hz, 1H), 3.15 (d, $J = 2.6$ Hz, 1H), 2.77 (dd, $J = 10.9$, 1.2 Hz, 1H), 1.47 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.5, 163.8, 161.3, 150.6, 142.0 (d, $J_{C-F} = 133.5$ Hz), 130.5 (d, $J_{C-F} = 7.5$ Hz), 130.1 (d, $J_{C-F} = 6.0$ Hz), 129.1, 128.3, 127.9, 127.5, 126.1, 125.0, 120.3 (d, $J_{C-F} = 22.1$ Hz), 114.9 (d, $J_{C-F} = 21$ Hz), 75.6, 71.1, 67.0, 52.1, 22.8. HRMS ($m/z$) (ESI): calcd for $C_{22}H_{19}FNaO_{3}Se$ 453.0376 [M+Na]$^+$ found 453.0372.

(±)-3-((3-Fluorophenyl)selanyl)-5-hydroxy-8a-methyl-4-phenyl-4a,8a-dihydro-2H-chromen-6(5H)-one (3v). Yellow oil, 51.6 mg, 40% yield. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.30 – 7.22 (m, 4H), 7.18 – 7.16 (m, 4H), 7.10 – 7.09 (m, 1H), 6.64 (d, $J = 10.0$ Hz, 1H), 6.06 (d, $J = 10.0$ Hz, 1H), 4.50 (dd, $J = 10.9$, 2.6 Hz, 1H), 4.32 (d, $J = 17.3$ Hz, 1H), 4.15 (dd, $J = 17.3$, 1.6 Hz, 1H), 3.15 (d, $J = 2.6$ Hz, 1H), 2.77 (dd, $J = 10.9$, 1.2 Hz, 1H), 1.47 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 199.5, 163.8, 161.3, 150.6, 142.0 (d, $J_{C-F} = 133.5$ Hz), 130.5 (d, $J_{C-F} = 7.5$ Hz), 130.1 (d, $J_{C-F} = 6.0$ Hz), 129.1, 128.3, 127.9, 127.5, 126.1, 125.0, 120.3 (d, $J_{C-F} = 22.1$ Hz), 114.9 (d, $J_{C-F} = 21$ Hz), 75.6, 71.1, 67.0, 52.1, 22.8. HRMS ($m/z$) (ESI): calcd for $C_{22}H_{19}FNaO_{3}Se$ 453.0376 [M+Na]$^+$ found 453.0372.
1H), 2.75 (dd, J = 10.9, 1.1 Hz, 1H), 2.29 (s, 3H), 1.47 (s, 3H). $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 199.6, 150.7, 142.7, 140.7, 139.9, 134.1, 130.2, 128.9, 128.2, 127.9, 127.3, 126.7, 126.0, 125.3, 75.7, 71.1, 66.8, 52.0, 22.8, 22.7. HRMS ($m/z$) (ESI): calcd for C$_{23}$H$_{22}$NaO$_3$Se 449.0626 [M+Na]$^+$ found 449.0620.

(±)-(Z)-4-hydroxy-7a-methyl-3-((phenylselanyl)methylene)-2,3,3a,7a-tetrahydrobenzofuran-5(4H)-one (5). Yellow oil, 64.5 mg, 64% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.50 – 7.45 (m, 2H), 7.32 – 7.27 (m, 3H), 6.73 (dd, $J = 5.6$, 4.5 Hz, 2H), 6.10 (d, $J = 10.2$ Hz, 1H), 4.60 (ddd, $J = 14.3$, 2.4, 1.5 Hz, 1H), 4.52 (dd, $J = 14.2$, 2.4 Hz, 1H), 4.24 (d, $J = 9.8$ Hz, 1H), 3.39 (s, 1H), 2.84 (d, $J = 9.8$ Hz, 1H), 1.41 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 198.6, 148.7, 143.5, 131.5, 130.6, 129.3, 127.13 126.1, 113.3, 80.0, 71.9, 70.3, 57.0, 25.8. HRMS ($m/z$) (ESI): calcd for C$_{16}$H$_{16}$NaO$_3$Se 359.0157 [M+Na]$^+$ found 359.0152.

(±)-8a-Methyl-4-phenyl-3,5-bis(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (4a). Yellow oil, 110.9 mg, 67% yield. $^1$H NMR (600 MHz, CDCl$_3$) $\delta$ 7.62 (dd, $J = 4.9$, 2.9 Hz, 2H), 7.47 – 7.46 (m, 2H), 7.37 – 7.36 (m, 3H), 7.29 – 7.28 (m, 3H), 7.26 – 7.25 (m, 5H), 6.55 (d, $J = 10.2$ Hz, 1H), 6.09 (dd, $J = 10.2$, 1.3 Hz, 1H), 4.41 (d, $J = 17.1$ Hz, 1H), 4.21 (dd, $J = 17.1$, 2.4 Hz, 1H), 3.53 (dd, $J = 4.2$, 1.3 Hz, 1H), 3.17 (dd, $J = 4.0$, 2.4 Hz, 1H), 1.54 (s, 3H). $^{13}$C NMR (150 MHz, CDCl$_3$) $\delta$ 194.3, 147.2, 139.6, 139.0, 134.3, 133.1, 130.5, 129.3, 129.1, 128.9, 128.5, 128.4, 128.2, 128.1, 127.4, 127.3, 126.6, 68.8, 66.0, 48.9, 47.8, 22.9. HRMS ($m/z$) (ESI): calcd for C$_{28}$H$_{26}$NaO$_2$Se$_2$ 574.9999 [M+Na]$^+$ found 575.0002.
(±)-8a-Methyl-3,5-bis(phenylselanyl)-4-(4-(trifluoromethyl)phenyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (4b). Yellow solid, mp 169-171°C, 139.5 mg, 79% yield. 

\[^1^H\text{NMR}\ (600 \text{ MHz, CDCl}_3) \delta \ 7.62 - 7.56 \ (m, \ 4H), \ 7.46 \ (dd, \ J = 7.4, \ 3.3 \ Hz, \ 4H), \ 7.28 \ (dd, \ J = 15.9, \ 4.6 \ Hz, \ 6H), \ 6.56 \ (d, \ J = 10.2 \ Hz, \ 1H), \ 6.10 \ (d, \ J = 10.2 \ Hz, \ 1H), \ 4.42 \ (d, \ J = 17.4 \ Hz, \ 1H), \ 4.25 \ (dd, \ J = 17.4, \ 1.9 \ Hz, \ 1H), \ 3.45 \ (d, \ J = 3.4 \ Hz, \ 1H), \ 3.13 \ (s, \ 1H), \ 1.55 \ (s, \ 3H). \]

\[^{13}\text{C NMR}\ (100 \text{ MHz, CDCl}_3) \delta \ 194.0, \ 147.0, \ 143.2, \ 137.5, \ 134.1, \ 133.2, \ 130.4, \ 130.3, \ 130.1, \ 129.4, \ 129.2, \ 128.9, \ 128.4, \ 128.3, \ 128.2, \ 127.7, \ 127.3, \ 125.5 \ (q, \ J = 3.7 \ Hz), \ 68.7, \ 65.9, \ 48.6, \ 47.6, \ 22.9.\]

HRMS (m/z) (ESI): calcd for C\textsubscript{29}H\textsubscript{23}F\textsubscript{3}NaO\textsubscript{2}Se\textsubscript{2} 642.9873 [M+Na]\textsuperscript{+} found 642.9875.

(±)-4-([1,1'-Biphenyl]-4-yl)-8a-methyl-3,5-bis(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (4c). Yellow oil, 116.7 mg, 62% yield. 

\[^1^H\text{NMR}\ (600 \text{ MHz, CDCl}_3) \delta \ 7.72 \ (dd, \ J = 7.5, \ 1.8 \ Hz, \ 2H), \ 7.66 \ (dd, \ J = 12.6, \ 4.7 \ Hz, \ 4H), \ 7.57 \ (dd, \ J = 7.9, \ 1.3 \ Hz, \ 2H), \ 7.52 \ (t, \ J = 8.0 \ Hz, \ 4H), \ 7.42 \ (t, \ J = 7.4 \ Hz, \ 1H), \ 7.37 - 7.28 \ (m, \ 6H), \ 6.62 \ (d, \ J = 10.2 \ Hz, \ 1H), \ 6.17 \ (dd, \ J = 10.2, \ 1.1 \ Hz, \ 1H), \ 4.51 \ (d, \ J = 17.1 \ Hz, \ 1H), \ 4.31 \ (dd, \ J = 17.2, \ 2.2 \ Hz, \ 1H), \ 3.66 \ (dd, \ J = 4.1, \ 1.1 \ Hz, \ 1H), \ 3.28 \ (dd, \ J = 3.7, \ 2.1 \ Hz, \ 1H), \ 1.61 \ (s, \ 3H). \]

\[^{13}\text{C NMR}\ (150 \text{ MHz, CDCl}_3) \delta \ 194.2, \ 147.1, \ 141.1, \ 140.4, \ 138.6, \ 138.3, \ 134.2, \ 133.0, \ 130.3, \ 129.3, \ 129.0, \ 128.9, \ 128.7, \ 128.2, \ 127.4, \ 127.3, \ 127.2, \ 127.1, \ 127.0, \ 126.5, \ 68.7, \ 66.0, \ 49.0, \ 47.6, \ 22.8.\]

HRMS (m/z) (ESI): calcd for C\textsubscript{34}H\textsubscript{26}NaO\textsubscript{2}Se\textsubscript{2} 651.0312 [M+Na]\textsuperscript{+} found 651.0316.
(±)-4-(8a-Methyl-6-oxo-3,5-bis(phenylselanyl)-4a,5,6,8a-tetrahydro-2H-chromen-4-yl)benzaldehyde (4d). Yellow oil, 130.5 mg, 75% yield. ¹H NMR (400 MHz, CDCl₃) δ 10.02 (s, 1H), 7.87 (d, J = 8.2 Hz, 2H), 7.62 – 7.56 (m, 2H), 7.52 (d, J = 8.1 Hz, 2H), 7.49 – 7.43 (m, 2H), 7.27 (ddd, J = 10.2, 6.4, 2.5 Hz, 6H), 6.55 (d, J = 10.2 Hz, 1H), 6.10 (dd, J = 10.2, 1.3 Hz, 1H), 4.43 (d, J = 17.4 Hz, 1H), 4.24 (dd, J = 17.4, 2.3 Hz, 1H), 3.45 (dd, J = 4.0, 1.2 Hz, 1H), 3.16 (dd, J = 4.0, 2.3 Hz, 1H), 1.55 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 194.0, 191.5, 147.0, 145.9, 135.9, 134.2, 133.2, 130.3, 129.9, 129.5, 129.3, 129.2, 128.4, 128.3, 128.3, 127.8, 127.4, 68.7, 66.0, 48.7, 47.6, 22.9. HRMS (m/z) (ESI): calcd for C₂₉H₂₄NaO₃Se₂ 602.9948 [M+Na]⁺ found 602.9973.

(±)-4-(4-Acetylphenyl)-8a-methyl-3,5-bis(phenylselanyl)-4a,8a-dihydro-2H-chromen-6(5H)-one (4e). Yellow oil, 128.3 mg, 72% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.94 (d, J = 8.3 Hz, 2H), 7.63 – 7.56 (m, 2H), 7.46 (ddd, J = 8.3, 4.8, 3.1 Hz, 4H), 7.32 – 7.24 (m, 6H), 6.55 (d, J = 10.2 Hz, 1H), 6.10 (dd, J = 10.2, 1.2 Hz, 1H), 4.42 (d, J = 17.3 Hz, 1H), 4.23 (dd, J = 17.3, 2.1 Hz, 1H), 3.47 (dd, J = 4.0, 1.2 Hz, 1H), 3.16 (dd, J = 4.0, 2.1 Hz, 1H), 2.61 (s, 3H), 1.54 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 197.4, 194.1, 147.0, 144.5, 138.0, 136.7, 134.2, 133.1, 130.3, 129.4, 129.2, 128.8, 128.6, 128.5, 128.3, 128.0, 127.7, 127.3, 68.7, 66.0, 48.7, 47.6, 26.6, 22.9. HRMS (m/z) (ESI): calcd for C₃₀H₂₆NaO₃Se₂ 617.0105 [M+Na]⁺ found 617.0108.

(±)-Methyl 4-(8a-methyl-6-oxo-3,5-bis(phenylselanyl)-4a,5,6,8a-tetrahydro-2H-chromen-4-yl)benzaldehyde (4d). Yellow oil, 130.5 mg, 75% yield. ¹H NMR (400 MHz, CDCl₃) δ 10.02 (s, 1H), 7.87 (d, J = 8.2 Hz, 2H), 7.62 – 7.56 (m, 2H), 7.52 (d, J = 8.1 Hz, 2H), 7.49 – 7.43 (m, 2H), 7.27 (ddd, J = 10.2, 6.4, 2.5 Hz, 6H), 6.55 (d, J = 10.2 Hz, 1H), 6.10 (dd, J = 10.2, 1.3 Hz, 1H), 4.43 (d, J = 17.4 Hz, 1H), 4.24 (dd, J = 17.4, 2.3 Hz, 1H), 3.45 (dd, J = 4.0, 1.2 Hz, 1H), 3.16 (dd, J = 4.0, 2.3 Hz, 1H), 1.55 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 194.0, 191.5, 147.0, 145.9, 135.9, 134.2, 133.2, 130.3, 129.9, 129.5, 129.3, 129.2, 128.4, 128.3, 128.3, 127.8, 127.4, 68.7, 66.0, 48.7, 47.6, 22.9. HRMS (m/z) (ESI): calcd for C₂₉H₂₄NaO₃Se₂ 602.9948 [M+Na]⁺ found 602.9973.
tetrahydro-2H-chromen-4-yl)benzoate (4f). Yellow oil, 148.2 mg, 81% yield. $^1$H NMR (400 MHz, CDCl$_3$) δ 8.03 (d, $J = 8.3$ Hz, 2H), 7.66 – 7.57 (m, 2H), 7.45 (ddd, $J = 15.1$, 8.1, 4.9 Hz, 4H), 7.30 – 7.22 (m, 6H), 6.54 (d, $J = 10.2$ Hz, 1H), 6.09 (d, $J = 10.2$ Hz, 1H), 4.41 (d, $J = 17.3$ Hz, 1H), 4.22 (dd, $J = 17.3$, 2.3 Hz, 1H), 3.93 (s, 3H), 3.47 (dd, $J = 4.0$, 1.2 Hz, 1H), 3.15 (dd, $J = 4.0$, 2.3 Hz, 1H), 1.53 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 194.0, 166.5, 147.0, 144.2, 138.0, 134.2, 133.2, 130.3, 129.8, 129.7, 129.3, 129.2, 128.5, 128.4, 128.3, 127.9, 127.6, 127.3, 68.6, 65.9, 52.2, 48.7, 47.5, 22.8. HRMS (m/z) (ESI): calcd for C$_{30}$H$_{26}$NaO$_4$Se$_2$ 633.0054 [M+Na]$^+$ found 633.0060.

(±)-3-(8a-Methyl-6-oxo-3,5-bis(phenylselanyl)-4a,5,6,8a-tetrahydro-2H-chromen-4-yl)benzonitrile (4g). Yellow oil, 150.6 mg, 87% yield. $^1$H NMR (600 MHz, CDCl$_3$) δ 7.72 (d, $J = 7.5$, 1.8 Hz, 2H), 7.66 (dd, $J = 12.6$, 4.7 Hz, 4H), 7.57 (dd, $J = 7.9$, 1.3 Hz, 2H), 7.52 (t, $J = 8.0$ Hz, 4H), 7.42 (t, $J = 7.4$ Hz, 1H), 7.37 – 7.28 (m, 6H), 6.62 (d, $J = 10.2$ Hz, 1H), 6.17 (dd, $J = 10.2$, 1.1 Hz, 1H), 4.51 (d, $J = 17.1$ Hz, 1H), 4.31 (dd, $J = 17.2$, 2.2 Hz, 1H), 3.66 (dd, $J = 4.1$, 1.1 Hz, 1H), 3.28 (dd, $J = 3.7$, 2.1 Hz, 1H), 1.61 (s, 3H). $^{13}$C NMR (150 MHz, CDCl$_3$) δ 194.0, 147.0, 140.7, 136.3, 134.2, 133.3, 133.0, 132.1, 131.6, 130.1, 129.4, 129.3, 129.2, 128.4, 128.0, 127.9, 127.3, 118.2, 112.7, 68.6, 65.8, 48.6, 47.5, 22.8. HRMS (m/z) (ESI): calcd for C$_{29}$H$_{23}$NNaO$_2$Se$_2$ 599.9951 [M+Na]$^+$ found 599.9956.

(±)-3-(8a-Methyl-6-oxo-3,5-bis(phenylselanyl)-4a,5,6,8a-tetrahydro-2H-chromen-4-yl)benzonitrile (4g). Yellow oil, 150.6 mg, 87% yield. $^1$H NMR (600 MHz, CDCl$_3$) δ 7.72 (d, $J = 7.5$, 1.8 Hz, 2H), 7.66 (dd, $J = 12.6$, 4.7 Hz, 4H), 7.57 (dd, $J = 7.9$, 1.3 Hz, 2H), 7.52 (t, $J = 8.0$ Hz, 4H), 7.42 (t, $J = 7.4$ Hz, 1H), 7.37 – 7.28 (m, 6H), 6.62 (d, $J = 10.2$ Hz, 1H), 6.17 (dd, $J = 10.2$, 1.1 Hz, 1H), 4.51 (d, $J = 17.1$ Hz, 1H), 4.31 (dd, $J = 17.2$, 2.2 Hz, 1H), 3.66 (dd, $J = 4.1$, 1.1 Hz, 1H), 3.28 (dd, $J = 3.7$, 2.1 Hz, 1H), 1.61 (s, 3H). $^{13}$C NMR (150 MHz, CDCl$_3$) δ 194.0, 147.0, 140.7, 136.3, 134.2, 133.3, 133.0, 132.1, 131.6, 130.1, 129.4, 129.3, 129.2, 128.4, 128.0, 127.9, 127.3, 118.2, 112.7, 68.6, 65.8, 48.6, 47.5, 22.8. HRMS (m/z) (ESI): calcd for C$_{29}$H$_{23}$NNaO$_2$Se$_2$ 599.9951 [M+Na]$^+$ found 599.9956.

(±)-3-(8a-Methyl-6-oxo-3,5-bis(phenylselanyl)-4a,5,6,8a-tetrahydro-2H-chromen-4-yl)benzonitrile (4g). Yellow oil, 150.6 mg, 87% yield. $^1$H NMR (600 MHz, CDCl$_3$) δ 7.72 (d, $J = 7.5$, 1.8 Hz, 2H), 7.66 (dd, $J = 12.6$, 4.7 Hz, 4H), 7.57 (dd, $J = 7.9$, 1.3 Hz, 2H), 7.52 (t, $J = 8.0$ Hz, 4H), 7.42 (t, $J = 7.4$ Hz, 1H), 7.37 – 7.28 (m, 6H), 6.62 (d, $J = 10.2$ Hz, 1H), 6.17 (dd, $J = 10.2$, 1.1 Hz, 1H), 4.51 (d, $J = 17.1$ Hz, 1H), 4.31 (dd, $J = 17.2$, 2.2 Hz, 1H), 3.66 (dd, $J = 4.1$, 1.1 Hz, 1H), 3.28 (dd, $J = 3.7$, 2.1 Hz, 1H), 1.61 (s, 3H). $^{13}$C NMR (150 MHz, CDCl$_3$) δ 194.0, 147.0, 140.7, 136.3, 134.2, 133.3, 133.0, 132.1, 131.6, 130.1, 129.4, 129.3, 129.2, 128.4, 128.0, 127.9, 127.3, 118.2, 112.7, 68.6, 65.8, 48.6, 47.5, 22.8. HRMS (m/z) (ESI): calcd for C$_{29}$H$_{23}$NNaO$_2$Se$_2$ 599.9951 [M+Na]$^+$ found 599.9956.
17.5, 2.3 Hz, 1H), 3.71 (dd, $J = 4.2, 1.3$ Hz, 1H), 3.18 (dd, $J = 4.1, 2.3$ Hz, 1H), 1.50 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 194.2, 147.1, 140.5, 134.7, 133.6, 131.5, 130.6, 129.4, 129.1, 129.0, 128.4, 128.3, 127.8, 127.5, 127.3, 127.0, 126.2, 68.9, 66.5, 49.8, 48.5, 22.8. HRMS (m/z) (ESI): calcd for C$_{26}$H$_{22}$NaO$_2$Se$_2$ 580.9563 [M+Na]$^+$ found 580.9567.

![Chemical Structure](image)

(±)-8a-Methyl-4-phenyl-3-(phenylselanyl)-5-((2,2,6,6-tetramethylpiperidin-1-yl)oxy)-4a,8a-dihydro-2H-chromen-6(5H)-one ($\mathbf{6}$). Yellow oil, 115.8 mg, 70% yield. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.29 – 7.19 (m, 5H), 7.17 – 7.11 (m, 3H), 7.02 (s, 2H), 6.51 (dd, $J = 10.4, 1.0$ Hz, 1H), 6.05 (dd, $J = 10.4, 1.3$ Hz, 1H), 3.98 (dd, $J = 16.5, 3.0$ Hz, 1H), 3.87 (dd, $J = 16.5, 1.7$ Hz, 1H), 3.78 (dd, $J = 2.5, 1.5$ Hz, 1H), 3.47 (s, 1H), 1.67 (s, 3H), 1.41 – 1.24 (m, 6H), 0.99 (s, 3H), 0.91 (s, 3H), 0.75 (s, 3H), 0.60 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 197.5, 150.1, 138.9, 135.7, 133.7, 129.9, 129.0, 128.5, 128.1, 128.0, 127.6, 127.5, 85.3, 72.6, 65.2, 52.0, 28.4, 16.8. HRMS (m/z) (ESI): calcd for C$_{31}$H$_{37}$NNaO$_3$Se 574.1831 [M+Na]$^+$ found 574.1824.

References


NMR Spectra for All Compounds

$^1$H NMR of 3a

$^{13}$C NMR of 3a
$^1$H NMR of 3b

$^{13}$C NMR of 3b
$^1$H NMR of 3c

$^{13}$C NMR of 3c
$^1$H NMR of 3d

$^{13}$C NMR of 3d
$^1$H NMR of 3e

$^{13}$C NMR of 3e
$^1$H NMR of 3f

$^{13}$C NMR of 3f
$^1$H NMR of $3g$

$^{13}$C NMR of $3g$
$^1$H NMR of 3h

$^{13}$C NMR of 3h
$^1$H NMR of 3i

$^{13}$C NMR of 3i
$^1$H NMR of 3j

$^{13}$C NMR of 3j
$^1$H NMR of 3k

$^{13}$C NMR of 3k
$^1$H NMR of 31

$^{13}$C NMR of 31
$^1$H NMR of $3m$

$^{13}$C NMR of $3m$
$^1$H NMR of 3p

$^{13}$C NMR of 3p
$^1$H NMR of 3q

$^{13}$C NMR of 3q
$^1$H NMR of 3r

$^{13}$C NMR of 3r
$^1$H NMR of 3s

$^{13}$C NMR of 3s
$^1$H NMR of 3t

$^{13}$C NMR of 3t
$^1$H NMR of 3u

$^{13}$C NMR of 3u
$^1$H NMR of 3v

$^{13}$C NMR of 3v
$^1$H NMR of 3w

$^{13}$C NMR of 3w
$^1$H NMR of 5

$^{13}$C NMR of 5
COSY of 5

HMBC of 5
HSQC of 5
$^1$H NMR of 4a

$^{13}$C NMR of 4a
$^{1}H$ NMR of 4c

$^{13}C$ NMR of 4c
$^1$H NMR of 4d

$^{13}$C NMR of 4d
$^{1}H$ NMR of 4e

$^{13}C$ NMR of 4e
$^1$H NMR of 4g

$^{13}$C NMR of 4g
\[^1\text{H} \text{NMR of} \ 4h\]

\[^{13}\text{C} \text{NMR of} \ 4h\]
$^1$H NMR of 6

$^{13}$C NMR of 6
HRMS Spectra for 6 and O-3a

HRMS of 6

HRMS (m/z) (ESI): calcd for C$_{31}$H$_{37}$NNaO$_3$Se 574.1831 [M+Na]$^+$ found 574.1824.

HRMS of $^{18}$O-3a

HRMS (m/z) (ESI): calcd for C$_{22}$H$_{20}$KO$_3^{18}$Se 453.0252 [M+K]$^+$ found 453.0224.

HRMS (m/z) (ESI): calcd for C$_{22}$H$_{20}$KO$_3$Se 453.0215 [M+K]$^+$ found 453.0233.

HRMS of O-3a

HRMS (m/z) (ESI): calcd for C$_{22}$H$_{20}$NaO$_3$Se 435.0475 [M+Na]$^+$ found 435.0475.