Simultaneous Generation and Subsequent Cycloaddition of *ortho*-Quinonemethides and Cyclic Enecarbamates Promoted by a Gold / Lewis Acid Catalytic System

Patricia Fernández,[a][‡] Pedro Alonso,[a][‡] Francisco J. Fañanás,*[a] and Félix Rodríguez*[a]

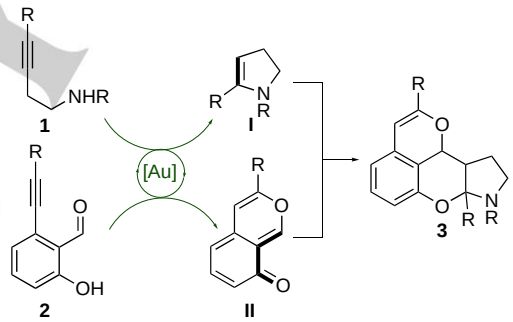
Dedication ((optional))

Abstract: A new catalytic reaction to synthesize structurally complex hexahydrochromeno[2,3-*b*]pyrrole derivatives from simple 3-butynamine and 2-(hydroxymethyl)phenol derivatives is described. The process is promoted by a dual catalytic system formed by a gold complex and a Lewis acid (boron trifluoride). The reaction involves the synchronized transformation of the starting materials into two reactive intermediates, a cyclic enamine derivative and an *ortho*-quinone methide, that subsequently react between them through a formal [4+2] cycloaddition to furnish the final poly-heterocyclic product in a straightforward way.

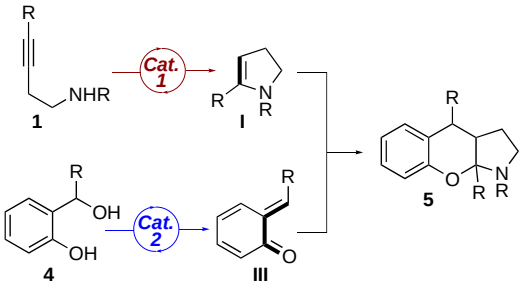
Introduction

In recent years, the development of new chemical transformations involving the intermediacy of *ortho*-quinone methides (*o*-QM) has experienced a considerable growth.[1] This kind of reactive species are usually in situ generated by treatment of appropriate precursors under acidic[2] or basic[3] conditions. They can be also accessed by elimination reactions promoted by different agents,[4] or through thermal processes.[5] Regarding the reactivity of *o*-QMs, they have been mainly used as heterodienes in cycloaddition processes.[4a,6] In this type of reactions, the corresponding *o*-QM is in situ generated in the presence of suitable cycloaddition partners. Moreover, the development of reactions where both the *o*-QM and the dienophile are catalytically and simultaneously generated, is an appealing research field. In this context, a gold-catalysed process recently reported by our group is to be mentioned (Scheme 1a).[7] In this reaction, the gold catalyst promotes the formation of enamines **I** (a dienophile) from alkynamines **1** and also the generation of isochromanone **II** (a heterodiene) from *ortho*-alkynylsalicylaldehyde **2**. The subsequent reaction between intermediates **I** and **II** leads to pyranochromeno[2,3-*b*]pyrrole derivatives **3**. In this context, we envisioned that 2-(hydroxymethyl)phenol derivatives **4** could be suitable precursors of *o*-QMs **III** (Scheme 1b). Since *o*-QMs usually behave as heterodienes in formal cycloaddition processes, intermediates **III** should react with cyclic enamines **I** delivering hexahydrochromeno[2,3-*b*]pyrrole derivatives **5**. In contrast with our previous work, the planned reaction would require two different catalysts to promote the formation of the heterodiene **III** and dienophile **I**.[8]

a) Our previous contribution (Ref. [7]):



b) New approach with a binary catalytic system (this work):



Scheme 1. Previous work and the new proposal for the synthesis of hexahydrochromeno[2,3-*b*]pyrrole derivatives.

With all this in mind, we initiated our investigation to find appropriate catalysts and conditions to perform the desired transformation. For the initial experiments, we selected *tert*-butyl [4-(4-bromophenyl)but-3-yn-1-yl]carbamate **1a** and 2-[hydroxyl(phenyl)methyl]phenol **4a** as model substrates. For the in-situ generation of the corresponding enecarbamates **I** from **1a** different gold catalysts were considered. On the other hand, the dehydration reaction of **4a** to obtain the corresponding *o*-QM **III**

[a] Instituto Universitario de Química Organometálica "Enrique Moles"
Universidad de Oviedo
Julián Clavería, 8; E-33006 Oviedo (Spain)
Fax: (+34) 985103446
E-mail: fjfv@uniovi.es; frodriguez@uniovi.es
http://personales.uniovi.es/web/soclab
[‡] These authors contributed equally to this work.

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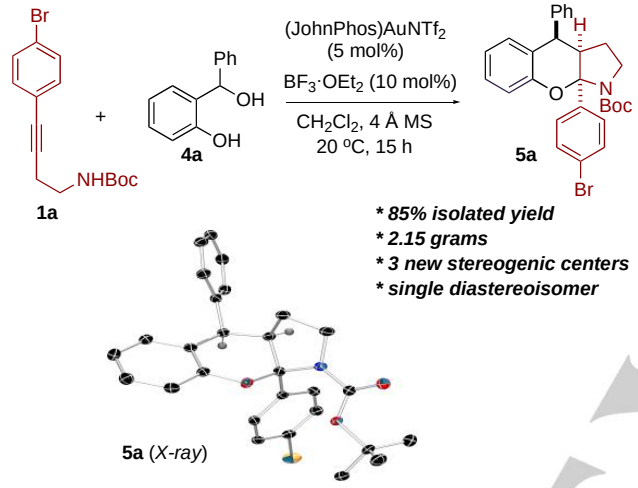
would require a Brønsted or Lewis acid as catalyst. In this sense, it should be noted that the use of binary metal / Brønsted acid catalytic systems are well documented in the bibliography and represents an appealing field to which our research group has recently contributed.[9,10] For this reason, we started our investigation by trying the model reaction in the presence of (JohnPhos)$AuNTf_2$ (5 mol%) as the gold-catalyst and different Brønsted acids (5 mol%) including triflic acid, tetrafluoroboric acid and diphenylphosphate among others. Although in some cases we observed the formation of the desired hexahydrochromeno[2,3-*b*]pyrrole **5a**, neither the yield nor the reproducibility were good.

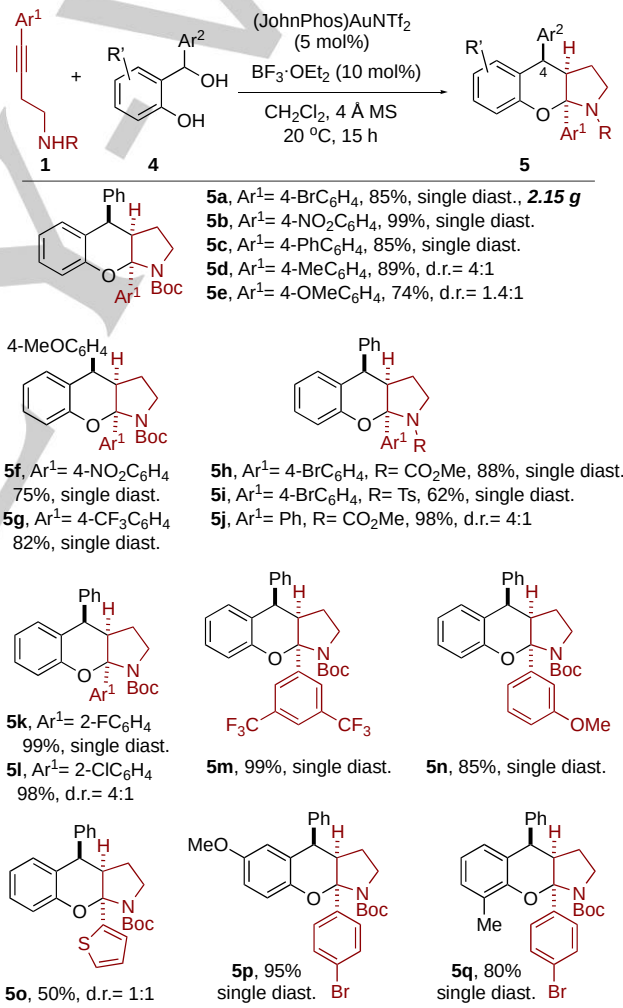


Scheme 2. Proof of concept and initial result.

At this point, we turned our attention to the use of a Lewis acid in combination with the gold-catalyst. It should be noted that this type of binary catalytic systems has been lesser used than those others formed by a gold-catalyst and a Brønsted acid.[11] However, after some experimentation we found that (JohnPhos)$AuNTf_2$ / $BF_3{\cdot}OEt_2$ was an appropriate catalytic system to promote the target transformation (Scheme 2). Thus, when diol **1a** and alkynamine **4a** (2 equiv) were reacted in dichloromethane at room temperature in the presence of 5 mol% of (JohnPhos)$AuNTf_2$ and 10 mol% of $BF_3{\cdot}OEt_2$ we observed the formation of hexahydrochromeno[2,3-*b*]pyrrole **5a** in almost quantitative yield (98%). Noteworthy, three new bonds and three stereogenic centres were created in this transformation. Furthermore, **5a** was obtained as a single diastereoisomer and the reaction could be scaled up to synthesize 2.15 grams of hexahydrochromeno[2,3-*b*]pyrrole **5a** in one batch without observing major changes in yield or diastereoselectivity. The structure of **5a** was determined by NMR studies and confirmed X-ray diffraction analysis.[12]

Results and Discussion

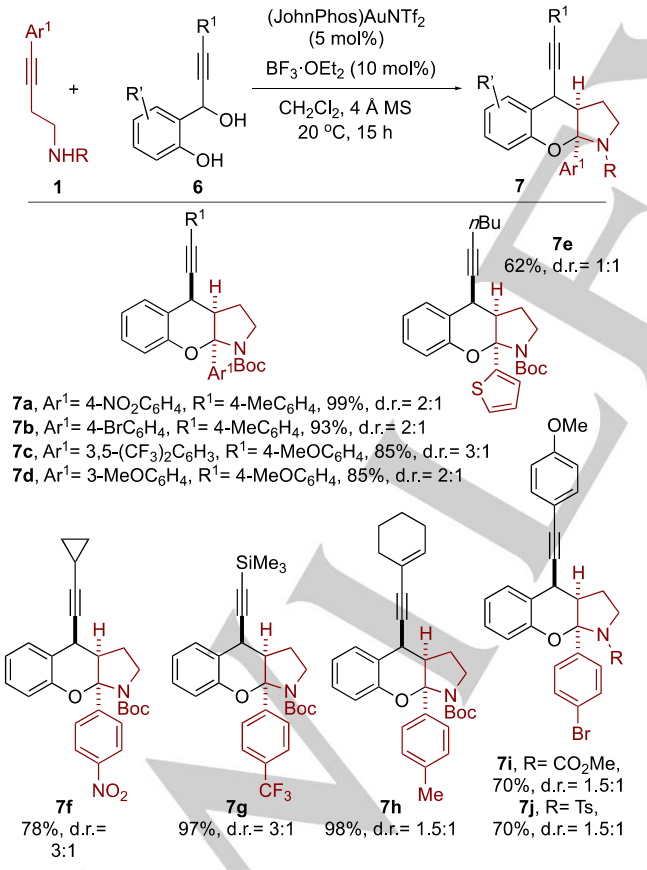
Having identified the optimized reaction conditions, we next studied the scope of the transformation using a series of substrates with different substitution patterns (Scheme 3). For the first set of experiments we used different 2-(hydroxymethyl)phenol derivatives **4** substituted with an aromatic group (Ar^2) in combination with a series of alkynamine derivatives **1** also substituted at the terminal position of the alkyne with an aromatic ring (Ar^1). Thus, as far as seventeen different hexahydrochromeno[2,3-*b*]pyrrole derivatives **5** could be accessed in good yields and as single diastereoisomers in most of the cases. In those cases where two diastereoisomers were obtained, the structure of the minor one differs from that of the major one only in the relative configuration of the stereocenter at 4-position (Scheme 3).



Scheme 3. Scope of the reaction with different arene-substituted 2-(hydroxymethyl)phenol derivatives **4**.

These results demonstrated that a wide range of substitution pattern was well tolerated. Thus, diverse substitution (*ortho*, *meta*, *para* and disubstitution) was allowed on the aromatic ring (Ar^1) of the initial alkynamine derivative **1**. However, we were not able to isolate the corresponding hexahydrochromeno[2,3-*b*]pyrrole derivatives when the alkynamine derivative **1** was unsubstituted at the terminal position of the alkyne or substituted with an alkyl group. Although most of the experiments were performed with alkynamine derivative **1** substituted with a *tert*-butoxycarbonyl group (Boc) on the nitrogen atom, we proved that other substituents such as a methoxycarbonyl (**5h,j**) or a tosyl group (**5i**) were also allowed. Regarding the substitution of the 2-(hydroxymethyl)phenol **4**, reactions with starting materials containing different aromatic rings (Ar^2) and substituents on the central arene (R') were successfully accomplished.

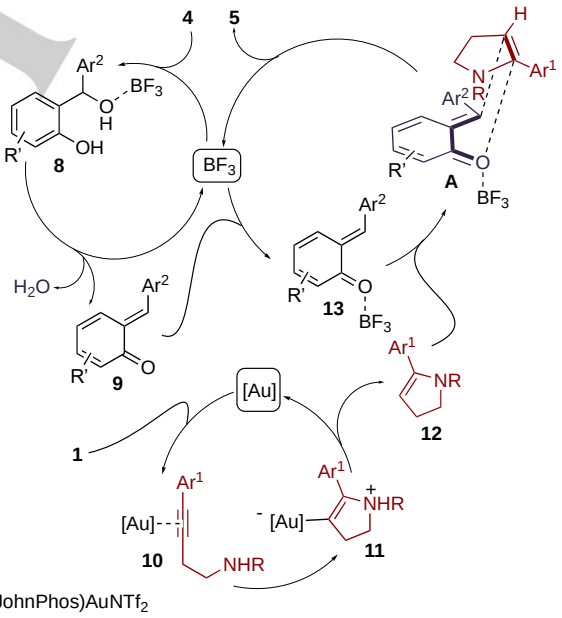
In order to expand the scope of the transformation we performed a second set of experiments with alkyne-containing 2-(hydroxymethyl)phenol derivatives **6** (Scheme 4). These precursors of *o*-QMs **III** are particularly interesting as they should lead to a new type of alkyne-substituted hexahydrochromeno[2,3-*b*]pyrrole derivatives **7** that could be further functionalized through reactions involving the carbon-carbon triple bond.



Scheme 4. Scope of the reaction with different alkyne-substituted 2-(hydroxymethyl)phenol derivatives **6**.

As shown, under the optimized reaction conditions previously found, we were able to obtain a series of products **7** in good to excellent yields but in these cases as mixtures of two diastereoisomers with selectivities ranging from 3:1 to 1:1 (Scheme 4). The structure of the major diastereoisomer is shown in scheme 4 while the minor diastereoisomer differs in the relative configuration of the stereocenter at propargylic position. Though, apart from aromatic rings (**7a-d**) and aliphatic groups (**7e**), the reaction tolerates the presence of other interesting substituents at the alkyne moiety of **6** (R^1). Thus, products with a cyclopropyl (**7f**), a trimethylsilyl (**7g**) or a cyclohexenyl (**7i**) could be isolated in excellent yields. Regarding the substitution of alkynamine derivative **1**, different aromatic rings (Ar^1) including heteroaromatics (**7e**) were tolerated at the alkynamine derivative **1**. As before, we were not able to obtain the desired hexahydrochromeno[2,3-*b*]pyrrole derivatives when the alkynamine derivative **1** was unsubstituted at the terminal position of the alkyne or substituted with an alkyl group. Finally, the *tert*-butoxycarbonyl (Boc) substituent on the nitrogen of alkynamine **1** could be replaced by methoxycarbonyl or tosyl groups (**7h,i**).

A plausible mechanism for the formation of hexahydrochromeno[2,3-*b*]pyrrole derivatives **5** (or **7**) involving three independent catalytic cycles is shown in Scheme 5.



Scheme 5. Mechanistic proposal.

In the first catalytic cycle, the Lewis acid (BF_3) coordinates the alcohol functionality of 2-(hydroxymethyl)phenol derivatives **4** to form the new species **8**. This coordination favours a dehydration reaction to generate the *ortho*-quinone methide (*o*-QM) derivative **9** in a process where the Lewis acid is regenerated. Simultaneously, the gold catalyst, JohnPhosAuNTf$_2$, coordinates the alkyne functionality of **1** as shown in **10**. This coordination

favours a 5-*endo* addition of the nitrogen atom to the alkyne to form intermediate **11**. A final protodemetalation step closes the second catalytic cycle affording the enamine derivative **12** and regenerating the gold catalyst. At this point, we propose that *o*-QM **9** enters a new catalytic cycle where the Lewis acid (BF_3) coordinates to the oxygen atom as shown in **13**. We propose that this coordination favours the subsequent formal [4+2] cycloaddition reaction of this adduct **13** with enamine derivative **12** to afford the hexahydrochromeno[2,3-*b*]pyrrole derivatives **5** regenerating the Lewis acid catalyst. The relative configuration observed at the new stereogenic centres in the single or major diastereoisomer of **5** could be explained through an endo approach of the dienophile and the diene as shown in **A** (endo refers to the orientation of the nitrogen in dienophile **12** with respect to the diene **13**). Interestingly, the global process could be considered a particular type of metal / Lewis acid relay one pot catalysis with two different catalysts and three independent catalytic cycles.[13]

Conclusions

In conclusion, a new protocol for the synthesis of hexahydrochromeno[2,3-*b*]pyrrole derivatives from simple 3-butynamine and 2-(hydroxymethyl)phenol derivatives has been developed. The reaction required the use of a dual catalytic system consisting of a gold complex and a Lewis acid, boron trifluoride. The cited catalytic system promotes the in-situ formation of an enecarbamate and an *ortho*-quinone methide that subsequently suffer a formal [4+2] cycloaddition reaction to yield the final product. The reaction is shown to be straightforward, high-yielding and easy to scale-up, while it paves the way for interesting poly-heterocyclic products, which are otherwise difficult to obtain.

Experimental Section

General Procedure for the Synthesis of Hexahydrochromeno[2,3-*b*]pyrrole Derivatives 5 or 7: The corresponding alkynylamine **1** (0.3 mmol, 2 equiv.), diol **4** or **6** (0.15 mmol, 1 equiv.) and 4Å powder molecular sieves (25 mg) were placed in an oven-dried Schlenk flask under an argon atmosphere. Then, dry dichloromethane (1.5 mL), (JohnPhos)$AuNTf_2$ (0.015 mmol, 5 mol%) and $BF_3{\cdot}OEt_2$ (0.015 mmol, 10 mol%) were sequentially added at 20 ºC. The initially colourless solution turned reddish and was gently stirred at 20 ˚C for 15 hours. Then, 2 mL of hexane were added to the reaction mixture and the resulting suspension was filtered through a path of celite eluting with diethyl ether. Solvents were removed under reduced pressure and the crude was purified by flash column chromatography on silica gel using mixtures of hexane and ethyl acetate as eluent to give the corresponding pure products **5** or **7**.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(4-bromophenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5a):** White solid. R_f = 0.51 (hexane/ethyl acetate 5:1). Melting point: 225-227 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.50–7.45 (m, 2H), 7.36–7.22 (m, 6H), 7.13 (dd, *J* = 7.9, 1.6 Hz, 2H), 7.05 (d, *J* = 8.1 Hz, 1H), 6.87–6.83 (m, 2H), 3.94 (d, *J* = 5.8 Hz, 1H), 3.84 (app t, *J* = 9.8 Hz, 1H), 3.51 (td, *J* = 10.7, 6.9 Hz, 1H), 2.67 (dt, *J* = 13.0, 5.8 Hz, 1H), 2.01–1.89 (m, 1H), 1.70–1.61 (m, 1H), 1.23 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 153.5, 153.4, 142.3, 140.5, 131.2, 129.5, 128.9, 128.5, 128.3, 127.3, 127.1, 121.8, 121.3, 120.7, 116.3, 94.1, 80.2, 53.4, 46.6, 40.9, 28.0, 23.8. HMRS: calculated for $C_{28}H_{28}BrNNaO_3$ $[M+Na]^+$ 528.1144, found 528.1142.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(4-nitrophenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5b):** White solid. R_f = 0.19 (hexane/ethyl acetate 10:1). Melting point: 229-231 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 8.21 (d, *J* = 9.0 Hz, 2H), 7.56 (d, *J* = 9.0 Hz, 2H), 7.38–7.23 (m, 4H), 7.14–7.05 (m, 3H), 6.91–6.86 (m, 2H), 3.92–3.82 (m, 2H), 3.55 (td, *J* = 10.7, 6.9 Hz, 1H), 2.76–2.67 (m, 1H), 2.07–1.92 (m, 1H), 1.71 (dt, *J* = 12.5, 6.4 Hz, 1H), 1.22 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.3, 153.1, 150.5, 147.5, 140.0, 129.4, 129.0, 128.6, 128.6, 127.3, 126.5, 123.4, 121.6, 121.1, 116.4, 93.9, 80.7, 53.5, 46.7, 40.9, 28.0, 24.0. HMRS: calculated for $C_{28}H_{28}N_2NaO_5$ $[M+Na]^+$ 495.1890, found 495.1886.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-([1,1'-biphenyl]-4-yl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5c):** White solid. R_f = 0.50 (hexane/ethyl acetate 5:1). Melting point: 213-215 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.66–7.60 (m, 2H), 7.59–7.55 (m, 2H), 7.49–7.41 (m, 4H), 7.39–7.24 (m, 5H), 7.16 (dd, *J* = 7.9, 1.5 Hz, 2H), 7.10 (d, *J* = 8.0 Hz, 1H), 6.90–6.84 (m, 2H), 4.04 (d, *J* = 5.2 Hz, 1H), 3.86 (app t, *J* = 9.8 Hz, 1H), 3.57 (td, *J* = 10.7, 6.9 Hz, 1H), 2.85–2.71 (m, 1H), 2.09–1.90 (m, 1H), 1.68 (dt, *J* = 12.5, 6.4 Hz, 1H), 1.21 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.8, 153.7, 142.1, 140.8, 140.3, 129.6, 129.0, 128.7, 128.4, 128.3, 127.2, 127.0, 126.8, 125.9, 121.9, 120.5, 116.4, 94.5, 80.0, 53.5, 46.7, 41.0, 28.0, 23.9. HMRS: calculated for $C_{34}H_{33}NNaO_3$ $[M+Na]^+$ 526.2352, found 526.2345.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-4-phenyl-9a-(*p*-tolyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5d-major diast.):** White solid. R_f = 0.50 (hexane/ethyl acetate 5:1). Melting point: 199-201 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.35–7.21 (m, 6H), 7.16–7.11 (m, 4H), 7.06 (d, *J* = 8.1 Hz, 1H), 6.86–6.79 (m, 2H), 3.97 (d, *J* = 5.0 Hz, 1H), 3.81 (app t, *J* = 9.8 Hz, 1H), 3.52 (td, *J* = 10.7, 6.9 Hz, 1H), 2.77 – 2.63 (m, 1H), 2.37 (s, 3H), 2.01–1.87 (m, 1H), 1.70–1.58 (m, 1H), 1.20 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 154.0, 141.2, 140.2, 137.0, 129.8, 129.1, 128.9, 128.6, 128.4, 127.2, 125.6, 122.2, 120.6, 116.6, 94.8, 80.0, 53.7, 46.9, 41.2, 28.2, 24.1, 21.1. HMRS: calculated for $C_{29}H_{31}NNaO_3$ $[M+Na]^+$ 464.2196, found 464.2199.

***tert*-Butyl (3a*R**,4*S**,9a*R**)-4-phenyl-9a-(*p*-tolyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5d-minor diast.):** White solid. R_f = 0.34 (hexane/ethyl acetate 5:1). Melting point: 195-198 °C. **^{1}H NMR** (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.31–7.25 (m, 1H,), 7.14 (d, *J* = 8.0 Hz, 1H), 7.05–6.98 (m, 5H), 6.96–6.92 (m, 2H), 6.86 (d, *J* = 8.0 Hz, 2H), 6.79–6.74 (m, 2H), 4.07 (d, *J* = 3.6 Hz, 1H), 3.79–3.64 (m, 2H), 3.05–2.97 (m, 1H), 2.23 (s, 3H), 2.21–2.12 (m, 1H), 1.95–1.85 (m, 1H), 1.20 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.7, 142.9, 136.2, 130.1, 128.3, 128.2, 128.2, 128.0, 127.8, 125.8, 125.8, 123.8, 121.3, 117.5, 94.4, 79.7, 54.2, 46.1, 44.3, 28.0, 27.9, 20.7. HMRS: calculated for $C_{29}H_{31}NNaO_3$ $[M+Na]^+$ 464.2196, found 464.2195.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(4-methoxyphenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5e-major diast.):** Yellow solid. R_f = 0.37 (hexane/ethyl acetate 5:1). Melting point: 206-208 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.26–7.11 (m, 6H), 7.05–7.01 (m, 2H), 6.95 (d, *J* = 8.1 Hz, 1H), 6.79–6.71 (m, 4H), 3.87 (d, *J* = 5.2 Hz, 1H), 3.77–3.66 (m, 4H), 3.41 (td, *J* = 10.7, 6.9 Hz, 1H), 2.58 (dt, *J* = 13.1, 5.8 Hz, 1H), 1.91–1.76 (m, 1H), 1.57–1.47 (m, 1H), 1.11 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 159.3, 154.0,

141.2, 129.8, 129.2, 128.6, 128.4, 127.2, 126.9, 122.2, 120.6, 116.6, 113.8, 94.7, 80.0, 55.5, 53.6, 46.9, 41.3, 28.3, 24.0. HMRS: calculated for $C_{29}H_{31}NNaO_4$ $[M+Na]^+$ 480.2145, found 480.2147.

***tert*-Butyl (3a*R**,4*S**,9a*R**)-9a-(4-methoxyphenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5e-minor diast.):** Yellow solid. R_f = 0.17 (hexane/ethyl acetate 5:1). Melting point: 129-131 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.31–7.24 (m, 1H), 7.12 (d, *J* = 8.1 Hz, 1H), 7.07–7.00 (m, 5H), 6.95–6.92 (m, 2H), 6.81–6.72 (m, 2H), 6.62–6.55 (m, 2H), 4.08 (d, *J* = 3.3 Hz, 1H), 3.77–3.62 (m, 5H), 3.02 (ddd, *J* = 10.0, 6.9, 3.5 Hz, 1H), 2.20–2.09 (m, 1H,), 1.90–1.82 (m, 1H), 1.21 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 158.6, 153.6, 143.0, 130.2, 128.3, 128.2, 127.8, 127.1, 125.9, 121.3, 117.5, 113.0, 94.0, 79.7, 55.3, 54.1, 46.1, 44.2, 28.1, 27.9. HMRS: calculated for $C_{29}H_{31}NNaO_4$ $[M+Na]^+$ 480.2145, found 480.2142.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-4-(4-methoxyphenyl)-9a-(4-nitrophenyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5f):** Yellow solid. R_f = 0.39 (hexane/ethyl acetate 5:1). Melting point: 212-214 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 8.20 (d, *J* = 8.7 Hz, 2H), 7.55 (d, *J* = 8.7 Hz, 2H), 7.30–7.23 (m, 1H), 7.07 (d, *J* = 8.0 Hz, 1H), 7.02 (d, *J* = 8.5 Hz, 2H), 6.90–6.83 (m, 4H), 3.89–3.77 (m, 5H), 3.55 (td, *J* = 10.6, 7.1 Hz, 1H), 2.74–2.63 (m, 1H), 2.05–1.90 (m, 1H), 1.78–1.68 (m, 1H), 1.22 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 159.3, 153.5, 153.3, 150.8, 147.7, 132.2, 130.6, 129.2, 128.8, 126.7, 123.7, 122.3, 121.4, 116.6, 114.4, 94.2, 80.9, 55.5, 54.0, 47.0, 40.2, 28.3, 24.3. HMRS: calculated for $C_{29}H_{30}N_2NaO_6$ $[M+Na]^+$ 525.1996, found 525.1992.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-4-(4-methoxyphenyl)-9a-[4-(trifluoromethyl)phenyl)]-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5g):** White solid. R_f = 0.46 (hexane/ethyl acetate 5:1). Melting point: 219-221 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) δ 7.61 (d, *J* = 8.2 Hz, 2H), 7.50 (d, *J* = 8.2 Hz, 2H), 7.28–7.22 (m, 1H), 7.06 (d, *J* = 8.7 Hz, 1H), 7.03 (d, *J* = 8.6 Hz, 2H), 6.91–6.83 (m, 4H), 3.93–3.79 (m, 5H), 3.55 (td, *J* = 10.6, 7.0 Hz, 1H), 2.75–2.61 (m, 1H), 2.05–1.87 (m, 1H), 1.78–1.67 (m, 1H), 1.19 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) δ 159.2, 153.7, 153.6, 147.6, 132.5, 130.7, 130.0 (q, J_{CF} = 30.0 Hz), 129.2, 128.6, 126.2, 125.3, 124.2 (q, J_{CF} = 277.2 Hz), 122.4, 121.1, 116.6, 114.3, 94.3, 80.5, 55.5, 53.9, 46.9, 40.2, 28.2, 24.2. ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) −62.4. HMRS: calculated for $C_{30}H_{30}F_3NNaO_4$ $[M+Na]^+$ 548.2019, found 548.2024.

Methyl (3a*R,4*R**,9a*R**)-9a-(4-bromophenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5h):** White solid. R_f = 0.50 (hexane/ethyl acetate 5:1). Melting point: 197-199 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.37 (d, *J* = 8.6 Hz, 2H), 7.25–7.11 (m, 6H), 7.02 (d, *J* = 6.4 Hz, 2H), 6.98 (d, *J* = 8.1 Hz, 1H), 6.77–6.72 (m, 2H), 3.86 (d, *J* = 5.2 Hz, 1H), 3.74 (app t, *J* = 9.8 Hz, 1H), 3.55–3.37 (m, 4H), 2.68–2.52 (m, 1H), 2.02–1.77 (m, 1H), 1.57 (dt, *J* = 12.9, 6.6 Hz, 1H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 154.7, 153.2, 141.1, 140.4, 131.5, 129.5, 129.0, 128.5, 128.5, 127.2, 121.7, 121.7, 120.9, 116.5, 94.3, 53.0, 52.2, 46.9, 40.8, 24.1. HMRS: calculated for $C_{25}H_{22}BrNNaO_3$ $[M+Na]^+$ 486.0675, found 486.0676.

(3a*R,4*R**,9a*R**)-9a-(4-Bromophenyl)-4-phenyl-1-tosyl-1,2,3,3a,4,9a-hexahydrochromeno[2,3-*b*]pyrrole (5i):** Yellow solid. R_f = 0.66 (hexane/ethyl acetate 5:1). Melting point: 190-192 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 7.76 (d, *J* = 8.3 Hz, 2H), 7.42 (d, *J* = 8.6 Hz, 2H), 7.33–7.17 (m, 7H), 7.13 (t, *J* = 7.0 Hz, 1H), 6.98–6.92 (m, 2H), 6.75–6.71 (m, 3H), 3.77 (d, *J* = 5.1 Hz, 1H), 3.63–3.43 (m, 2H), 2.68 (dt, *J* = 12.5, 6.4 Hz, 1H), 2.39 (s, 3H), 1.85–1.65 (m, 1H), 1.60–1.50 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm) 152.8, 143.7, 140.2, 139.7, 136.7, 131.7, 129.5, 129.1, 128.8, 128.7, 128.7, 128.1, 127.4, 122.6, 121.3, 115.9, 96.7, 52.7, 47.8, 40.7, 24.0, 21.7. HMRS: calculated for $C_{30}H_{26}BrNNaO_3S$ $[M+Na]^+$ 582.0708, found 582.0712.

Methyl (3a*R,4*R**,9a*R**)-4,9a-diphenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5j-major diast.):** White solid. R_f = 0.32 (hexane/ethyl acetate 5:1). Melting point: 212-214 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.41–7.22 (m, 9H), 7.15–7.08 (m, 3H), 6.88–6.83 (m, 2H), 3.99 (d, *J* = 5.2 Hz, 1H), 3.86 (app t, *J* = 9.8 Hz, 1H), 3.63–3.51 (m, 4H), 2.81–2.68 (m, 1H), 2.07–1.92 (m, 1H), 1.68 (dt, *J* = 12.5, 6.4 Hz, 1H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 154.8, 153.5, 141.9, 140.7, 129.5, 128.9, 128.4, 128.3, 128.2, 127.6, 127.1, 125.3, 121.8, 120.6, 116.5, 94.7, 53.1, 52.0, 47.0, 40.8, 24.1. HMRS: calculated for $C_{25}H_{23}NNaO_3$ $[M+Na]^+$ 408.1570, found 408.1576.

Methyl (3a*R,4*S**,9a*R**)-4,9a-diphenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)- carboxylate (5j-minor diast.):** White solid. R_f = 0.26 (hexane/ethyl acetate 5:1). Melting point: 142-145 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.31–7.26 (m, 1H,), 7.20–7.13 (m, 3H), 7.10–7.05 (m, 3H), 7.04–7.00 (m, 3H), 6.96–6.93 (m, 2H), 6.80–6.74 (m, 2H), 4.10 (d, *J* = 3.7 Hz, 1H), 3.87–3.64 (m, 2H), 3.52 (s, 3H), 3.14–2.98 (m, 1H), 2.27–2.12 (m, 1H), 2.00–1.86 (m, 1H). ^{13}C NMR (75 MHz, 298K, $CDCl_3$): δ (ppm) 153.3, 153.2, 140.7, 130.3, 129.6, 129.0, 128.5, 128.4, 127.7, 127.1, 125.2, 121.6, 120.7, 117.6, 116.5, 94.3, 52.3, 46.9, 40.7, 24.0. HMRS: calculated for $C_{25}H_{23}NNaO_3$ $[M+Na]^+$ 408.1570, found 408.1576.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(2-fluorophenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5k):** White solid. R_f = 0.5 (hexane/ethyl acetate 5:1). Melting point: 226-228 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.50 (app t, *J* = 7.7 Hz, 1H), 7.36–7.23 (m, 5H), 7.15 (dd, *J* = 8.0, 1.5 Hz, 2H), 7.12–7.04 (m, 3H), 6.89–6.84 (m, 2H), 3.98 (d, *J* = 5.2 Hz, 1H), 3.78 (app t, *J* = 9.6 Hz, 1H), 3.53 (td, *J* = 10.8, 6.7 Hz, 1H), 3.06–2.96 (m, 1H), 2.02–1.85 (m, 1H), 1.71–1.60 (m, 1H), 1.20 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 158.7 (d, J_{CF} = 247.7 Hz), 153.3, 140.6, 129.5, 129.3, 128.8, 128.4, 128.3, 127.1, 123.8, 121.9, 120.7, 116.4, 115.9 (d, J_{CF} = 22.6 Hz), 92.1, 79.7, 50.1, 45.8, 41.3, 28.0, 23.9. ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) −110.8. HMRS: calculated for $C_{28}H_{28}FNNaO_3$ $[M+Na]^+$ 468.1945, found 468.1944.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(2-chlorophenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5l, diastereoisomeric mixture):** White solid. R_f = 0.66 (hexane/ethyl acetate 5:1). Melting point: 226-228 °C. *Only representative signals are listed:* ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.61 (d, *J* = 8.4 Hz, 1H, min diast), 7.54 (d, *J* = 7.7 Hz, 1H, maj diast), 7.07 (d, *J* = 8.1 Hz, 1H, maj diast), 3.31–3.21 (m, 1H, maj diast), 3.21–3.10 (m, 1H, min diast), 1.45 (s, 9H, min diast), 1.11 (s, 9H, maj diast). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.3, 153.3, 152.5, 140.6, 138.9, 137.8, 131.5, 131.3, 130.1, 129.6, 129.4, 129.1, 129.0, 128.8, 128.5, 128.4, 127.1, 126.8, 121.5, 120.7, 116.4, 116.1, 94.1, 93.5, 79.8, 47.8, 47.2, 45.9, 45.4, 41.1, 41.0, 28.4, 27.8, 24.6, 24.0. HMRS: calculated for $C_{28}H_{28}ClNNaO_3$ $[M+Na]^+$ 484.1649, found 484.1649.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(3,5-bis(trifluoromethyl)phenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5m):** White solid. R_f = 0.62 (hexane/ethyl acetate 5:1). Melting point: 162-164 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.89–7.84 (m, 3H), 7.39–7.27 (m, 4H), 7.14 (dd, *J* = 7.8, 1.7 Hz, 2H), 7.10 (d, *J* = 8.1 Hz, 1H), 6.96–6.86 (m, 2H), 3.93 (d, *J* = 5.5 Hz, 1H), 3.87 (app t, *J* = 10.3 Hz, 1H), 3.59 (td, *J* = 10.3, 7.0 Hz, 1H), 2.77 (dt, *J* = 12.3, 5.5 Hz, 1H), 2.07–1.94 (m, 1H), 1.76 (dt, *J* = 12.3, 6.4 Hz, 1H), 1.18 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.2, 152.9, 146.6, 139.7, 131.9 (q, J_{CF} = 33.6 Hz), 129.4, 128.9, 128.7, 128.6, 127.4, 125.9,

123.3 (q, J_{CF} = 266.0 Hz), 121.9, 121.4, 116.5, 93.7, 80.7, 53.7, 46.6, 40.8, 27.8, 23.9. ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) −62.8. HMRS: calculated for $C_{30}H_{27}F_6NNaO_3$ $[M+Na]^+$ 586.1787, found 586.1784.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(3-methoxyphenyl)-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5n):** White solid. R_f = 0.50 (hexane/ethyl acetate 5:1). Melting point: 158-160 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.35–7.20 (m, 5H), 7.16–7.12 (m, 2H), 7.06 (d, *J* = 8.0 Hz, 1H), 6.97–6.92 (m, 2H), 6.87–6.82 (m, 3H), 3.99 (d, *J* = 5.2 Hz, 1H), 3.85–3.79 (m, 1H), 3.76 (s, 3H), 3.53 (td, *J* = 10.7, 6.8 Hz, 1H), 2.77–2.66 (m, 1H), 2.01–1.87 (m, 1H), 1.64 (dt, *J* = 12.4, 6.4 Hz, 1H), 1.21 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 159.7, 153.8, 153.7, 144.8, 140.8, 129.5, 129.1, 128.9, 128.4, 128.2, 127.0, 121.9, 120.5, 117.9, 116.3, 112.7, 111.8, 94.4, 79.9, 55.2, 53.4, 46.7, 41.0, 28.0, 23.9. HMRS: calculated for $C_{29}H_{31}NNaO_4$ $[M+Na]^+$ 480.2145, found 480.2145.

***tert*-butyl (3a*R**,4*R**,9a*R**)-4-phenyl-9a-(thiophen-2-yl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5o-diast. 1):** White solid. R_f = 0.54 (hexane/ethyl acetate 5:1). Melting point: 181-183 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.37–7.20 (m, 5H), 7.17 (d, *J* = 6.9 Hz, 2H), 7.03 (d, *J* = 8.1 Hz, 1H), 6.97 (d, *J* = 2.3 Hz, 1H), 6.95–6.91 (m, 1H), 6.89–6.82 (m, 2H), 4.14 (d, *J* = 5.2 Hz, 1H), 3.76 (app t, *J* = 9.8 Hz, 1H), 3.50 (td, *J* = 10.7, 7.0 Hz, 1H), 2.92–2.76 (m, 1H), 1.98–1.85 (m, 1H), 1.68–1.55 (m, 1H), 1.30 (s, 9H). **^{13}C NMR** (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.7, 153.1, 146.6, 140.7, 129.6, 128.9, 128.5, 128.2, 127.1, 126.4, 124.8, 124.4, 121.9, 120.9, 116.7, 92.7, 80.2, 54.6, 46.4, 41.4, 28.1, 23.6. HMRS: calculated for $C_{26}H_{28}NO_3S$ $[M+H]^+$ 434.1784, found 434.1777.

***tert*-butyl (3a*R**,4*S**,9a*R**)-4-phenyl-9a-(thiophen-2-yl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5o-diast. 2):** White solid. R_f = 0.40 (hexane/ethyl acetate 5:1). Melting point: 120-122 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.28–7.24 (m, 1H), 7.16–7.08 (m, 4H), 7.02 (d, *J* = 4.9 Hz, 1H), 6.97–6.86 (m, 4H), 6.77 (d, *J* = 2.8 Hz, 1H), 6.74–6.69 (m, 1H), 4.08 (d, *J* = 4.2 Hz, 1H), 3.75–3.63 (m, 1H), 3.06–3.02 (m, 1H), 2.23 (td, *J* = 12.5, 6.8 Hz, 1H), 1.93–1.81 (m, 1H), 1.30 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 154.0, 153.5, 148.9, 143.1, 130.1, 128.7, 128.6, 128.5, 126.6, 126.1, 124.9, 124.5, 122.1, 118.1, 93.2, 80.5, 55.6, 46.0, 44.8, 28.5, 28.1. HMRS: calculated for $C_{26}H_{28}NO_3S$ $[M+H]^+$ 434.1784, found 434.1769.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(4-bromophenyl)-6-methoxy-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5p):** White solid. R_f = 0.58 (hexane/ethyl acetate 5:1). Melting point: 182-184 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.47 (d, *J* = 8.7 Hz, 2H), 7.38–7.22 (m, 5H), 7.17–7.10 (m, 2H), 6.99 (d, *J* = 8.8 Hz, 1H), 6.83 (ddd, *J* = 8.8, 3.0, 0.9 Hz, 1H), 6.41 (dd, *J* = 3.0, 1.1 Hz, 1H), 3.92 (d, *J* = 5.2 Hz, 1H), 3.82 (app t, *J* = 9.8 Hz, 1H), 3.65 (s, 3H), 3.56–3.42 (m, 1H), 2.72–2.60 (m, 1H), 2.01–1.86 (m, 1H), 1.64 (dt, *J* = 12.7, 6.5 Hz, 1H), 1.23 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.8, 153.6, 147.5, 142.4, 140.3, 131.2, 129.5, 128.5, 127.4, 127.2, 122.7, 121.2, 117.0, 114.4, 114.1, 94.0, 80.1, 55.6, 53.5, 46.6, 41.3, 28.0, 23.9. HMRS: calculated for $C_{29}H_{30}BrNNaO_4$ $[M+Na]^+$ 558.1250, found 558.1261.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(4-bromophenyl)-8-methyl-4-phenyl-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (5q):** White solid. R_f = 0.50 (hexane/ethyl acetate 5:1). Melting point: 219-212 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.47 (d, *J* = 8.2 Hz, 2H), 7.34–7.26 (m, 3H), 7.22 (d, *J* = 8.2 Hz, 2H), 7.16–7.10 (m, 3H), 6.77 (t, *J* = 7.4 Hz, 1H), 6.70 (d, *J* = 7.4 Hz, 1H), 3.96 (d, *J* = 4.4 Hz, 1H), 3.84 (t, *J* = 9.4 Hz, 1H), 3.56–3.43 (m, 1H), 2.75–2.63 (m, 1H), 2.36 (s, 3H), 2.01–1.84 (m, 1H), 1.72–1.61 (m, 1H), 1.21 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.8, 151.3, 143.0, 140.6, 131.2, 129.5, 129.5, 128.4, 127.2, 127.0, 126.4, 125.3, 121.8, 121.2, 120.2, 94.3, 80.0, 53.6, 46.7, 41.1, 28.0, 24.0, 15.9. HMRS: calculated for $C_{29}H_{30}BrNNaO_3$ $[M+Na]^+$ 542.1301, found 542.1297.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(4-nitrophenyl)-4-(*p*-tolylethynyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7a-major diast.):** Yellow solid. R_f = 0.45 (hexane/ethyl acetate 5:1). Melting point: 152-154 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 8.22 (d, *J* = 9.0 Hz, 2H), 7.65–7.56 (m, 3H), 7.37–7.29 (m, 3H), 7.13 (d, *J* = 7.9 Hz, 2H), 7.07 (td, *J* = 7.5, 1.1 Hz, 1H), 7.02 (d, *J* = 8.0 Hz, 1H), 3.96 (d, *J* = 4.6 Hz, 1H), 3.77 (app t, *J* = 9.7 Hz, 1H), 3.67 (td, *J* = 10.4, 7.2 Hz, 1H), 3.02 (ddd, *J* = 11.9, 7.1, 4.8 Hz, 1H), 2.36 (s, 3H), 2.30–2.19 (m, 1H), 1.90–1.77 (m, 1H), 1.24 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.1, 152.0, 150.9, 147.5, 138.5, 131.6, 129.0, 129.0, 128.3, 126.3, 123.5, 122.0, 120.6, 119.8, 116.8, 94.3, 85.6, 85.0, 80.7, 52.6, 46.8, 28.8, 28.0, 23.7, 21.3. HMRS: calculated for $C_{31}H_{30}N_2NaO_5$ $[M+Na]^+$ 533.2046, found 533.2049.

***tert*-Butyl (3a*R**,4*S**,9a*R**)-9a-(4-nitrophenyl)-4-(*p*-tolylethynyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7a-minor diast.):** Yellow solid. R_f = 0.23 (hexane/ethyl acetate 5:1). Melting point: 176-178 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 8.06 (d, *J* = 8.6 Hz, 2H), 7.61 (d, *J* = 8.6 Hz, 2H), 7.39–7.25 (m, 2H), 7.09 (d, *J* = 7.8 Hz, 1H), 7.03 (t, *J* = 7.3 Hz, 1H), 6.93 (d, *J* = 7.7 Hz, 2H), 6.76 (d, *J* = 7.7 Hz, 2H), 3.94 (s, 1H), 3.86–3.64 (m, 2H), 3.17–3.01 (m, 1H), 2.27 (s, 3H), 2.19–2.06 (m, 1H), 1.93–1.79 (m, 1H), 1.26 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.1, 151.6, 150.8, 147.2, 138.1, 130.9, 129.8, 129.2, 128.7, 127.1, 122.9, 122.0, 119.8, 119.4, 117.3, 93.0, 88.2, 83.6, 80.7, 52.1, 46.3, 29.8, 28.0, 26.8, 21.1. HMRS: calculated for $C_{31}H_{30}N_2NaO_5$ $[M+Na]^+$ 533.2046, found 533.2048.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(4-bromophenyl)-4-(*p*-tolylethynyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7b-major diast.):** Yellow solid. R_f = 0.64 (hexane/ethyl acetate 5:1). Melting point: 98-100 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.49 (ddd, *J* = 7.6, 1.9, 0.9 Hz, 1H), 7.37 (d, *J* = 8.4 Hz, 2H), 7.23 (d, *J* = 8.0 Hz, 2H), 7.20–7.12 (m, 3H), 7.01 (d, *J* = 8.0 Hz, 2H), 6.92 (t, *J* = 7.6, 1H), 6.88 (d, *J* = 8.1 Hz, 1H), 3.86 (d, *J* = 4.7 Hz, 1H), 3.64 (app t, *J* = 9.5 Hz, 1H), 3.52 (td, *J* = 10.5, 7.1 Hz, 1H), 2.85 (ddd, *J* = 12.0, 7.0, 4.8 Hz, 1H), 2.25 (s, 3H), 2.14–2.00 (m, 1H), 1.75–1.60 (m, 1H), 1.13 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.6, 152.5, 143.0, 138.5, 131.8, 131.5, 129.2, 129.0, 128.4, 127.3, 121.8, 120.7, 120.2, 116.9, 94.6, 86.4, 84.9, 80.4, 52.6, 46.9, 28.9, 28.2, 23.7, 21.5. HMRS: calculated for $C_{31}H_{30}BrNNaO_3$ $[M+Na]^+$ 566.1301, found 566.1300.

***tert*-Butyl (3a*R**,4*S**,9a*R**)-9a-(4-bromophenyl)-4-(*p*-tolylethynyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7b-minor diast.):** Yellow solid. R_f = 0.45 (hexane/ethyl acetate 5:1). Melting point: 187-189 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.28 (d, *J* = 8.7 Hz, 2H), 7.23–7.14 (m, 4H), 6.96 (d, *J* = 8.1 Hz, 1H), 6.93–6.86 (m, 3H), 6.76 (d, *J* = 8.1 Hz, 2H), 3.84 (d, *J* = 2.6 Hz, 1H), 3.71–3.62 (m, 1H,), 3.61–3.50 (m, 1H), 2.94 (ddd, *J* = 11.2, 6.8, 2.6 Hz, 1H), 2.20 (s, 3H), 2.04–1.93 (m, 1H), 1.83–1.69 (m, 1H), 1.13 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.7, 152.3, 143.0, 138.0, 131.6, 131.1, 129.9, 129.2, 129.0, 128.2, 121.9, 121.5, 120.4, 120.1, 117.5, 93.7, 88.5, 83.5, 80.5, 52.3, 46.5, 30.2, 28.3, 27.0, 21.5. HMRS: calculated for $C_{31}H_{30}BrNNaO_3$ $[M+Na]^+$ 566.1301, found 566.1310.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-[3,5-bis(trifluoromethyl)phenyl]-4-[(4-methoxyphenyl)ethynyl]2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7c-major diast.):** Yellow solid. R_f = 0.67 (hexane/ethyl acetate 5:1). Melting point: 97-99 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.81–7.73 (m, 3H), 7.54 (dt, *J* = 7.6, 1.5 Hz, 1H), 7.29 (d, *J* = 8.9 Hz, 2H), 7.21 (ddd, *J* = 8.0, 7.6, 1.5 Hz, 1H), 6.99 (t, *J* =

7.6 Hz, 1H), 6.92 (d, *J* = 8.0 Hz, 1H), 6.75 (d, *J* = 8.9 Hz, 2H), 3.88 (d, *J* = 4.5 Hz, 1H), 3.71 (s, 3H), 3.65–3.49 (m, 2H), 3.03–2.87 (m, 1H), 2.22–2.09 (m, 1H), 1.70 (ddt, *J* = 12.8, 11.7, 9.5 Hz, 1H), 1.09 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 159.9, 153.0, 151.9, 147.1, 133.0, 132.0 (q, J_{CF} = 33.5 Hz), 129.0, 128.1, 125.7, 123.2 (q, J_{CF} = 271.0 Hz), 122.3, 121.3, 117.0, 115.0, 114.1, 94.2, 85.1, 84.6, 80.7, 55.2, 53.1, 46.8, 28.9, 27.8, 23.6. ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) −62.7. HMRS: calculated for $C_{33}H_{29}F_6NNaO_4$ $[M+Na]^+$ 640.1893, found 640.1889.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-(3-methoxyphenyl)-4-[(4-methoxyphenyl)ethynyl]-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7d-major diast.):** Yellow solid. R_f = 0.43 (hexane/ethyl acetate 5:1). Melting point: 91-93 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.49 (dt, *J* = 7.6, 1.4 Hz, 1H), 7.27 (d, *J* = 8.9 Hz, 2H), 7.19–7.11 (m, 2H), 6.94–6.84 (m, 4H), 6.77–6.70 (m, 3H), 3.91 (d, *J* = 4.7 Hz, 1H), 3.71 (s, 3H), 3.68 (s, 3H), 3.67–3.60 (m, 1H), 3.57–3.50 (m, 1H), 2.91 (ddd, *J* = 12.0, 6.9, 4.8 Hz, 1H), 2.13–2.01 (m, 1H), 1.72–1.60 (m, 1H), 1.12 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 160.0, 159.9, 153.8, 152.7, 145.5, 133.3, 129.4, 128.9, 128.4, 121.5, 121.0, 117.9, 116.9, 115.5, 114.2, 113.0, 111.8, 94.9, 86.0, 84.5, 80.1, 55.5, 52.7, 46.9, 29.0, 28.2, 23.7. HMRS: calculated for $C_{32}H_{33}NNaO_5$ $[M+Na]^+$ 534.2250, found 534.2265.

***tert*-Butyl (3a*R**,4*S**,9a*R**)-9a-(3-methoxyphenyl)-4-[(4-methoxyphenyl)ethynyl]-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7d-minor diast.):** Yellow solid. R_f = 0.32 (hexane/ethyl acetate 5:1). Melting point: 178-180°C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.34 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.29–7.24 (m, 1H), 7.16 (t, *J* = 7.8 Hz, 1H), 7.07 (d, *J* = 8.1 Hz, 1H), 7.03–6.96 (m, 5H), 6.76–6.69 (m, 3H), 3.92 (d, *J* = 3.5 Hz, 1H), 3.78 (s, 3H), 3.67 (s, 3H), 3.77–3.70 (m, 2H), 3.09–3.00 (m, 1H), 2.16–2.07 (m, 1H), 1.94–1.86 (m, 1H), 1.22 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 159.4, 159.2, 152.5, 142.0, 132.9, 129.3, 129.2, 128.7, 128.7, 128.6, 128.3, 121.5, 118.4, 117.3, 115.4, 113.5, 112.6, 112.4, 94.0, 87.5, 82.8, 79.9, 55.1, 52.3, 46.1, 30.4, 28.0, 26.8. HMRS: calculated for $C_{32}H_{33}NNaO_5$ $[M+Na]^+$ 534.2250, found 534.2260.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-4-(hex-1-yn-1-yl)-9a-(thiophen-2-yl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7e-diast. 1):** Orange solid. R_f = 0.37 (hexane/ethyl acetate 7:1). Melting point: 99-101 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.52 (dt, *J* = 7.6, 1.4 Hz, 1H), 7.26–7.19 (m, 2H), 7.01 (td, *J* = 7.5, 1.2 Hz, 1H), 6.97–6.91 (m, 3H), 3.90 (s, 1H), 3.71–3.63 (m, 1H), 3.57 (td, *J* = 10.6, 7.0 Hz, 1H), 3.03 (ddd, *J* = 12.1, 7.0, 4.8 Hz, 1H), 2.27 (td, *J* = 7.0, 2.3 Hz, 2H,), 2.13–2.03 (m, 1H), 1.69–1.41 (m, 5H), 1.30 (s, 9H), 0.95 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.6, 151.9, 147.8, 128.4, 128.0, 126.5, 124.3, 123.8, 121.8, 121.6, 116.8, 93.2, 84.7, 80.1, 53.9, 46.3, 31.0, 28.5, 28.0, 23.2, 21.9, 18.4, 13.4. HMRS: calculated for $C_{26}H_{32}NO_3S$ $[M+H]^+$ 438.2097, found 438.2086.

***tert*-Butyl (3a*R**,4*S**,9a*R**)-4-(hex-1-yn-1-yl)-9a-(thiophen-2-yl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7e-diast. 2):** Orange solid. R_f = 0.33 (hexane/ethyl acetate 7:1). Melting point: 186-188 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.37 (d, *J* = 7.4 Hz, 1H), 7.27–7.22 (m, 1H), 7.15 (dd, *J* = 5.0, 1.3 Hz, 1H), 7.05 (d, *J* = 7.8 Hz, 1H), 7.00 (td, *J* = 7.4, 1.2 Hz, 1H), 6.94 (dd, *J* = 3.6, 1.3 Hz, 1H), 6.86 (dd, *J* = 5.0, 3.6 Hz, 1H), 3.80–3.64 (m, 3H), 2.82 (dd, *J* = 13.3, 7.0 Hz, 1H), 2.25–2.14 (m, 1H), 2.04–1.92 (m, 3H), 1.42–1.23 (m, 13H), 0.89 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.6, 152.3, 148.7, 128.4, 126.0, 124.1, 124.0, 123.0, 121.9, 117.5, 93.5, 84.0, 80.1, 78.6, 54.0, 45.4, 30.9, 30.6, 28.1, 26.4, 21.8, 18.3, 13.4. HMRS: calculated for $C_{26}H_{32}NO_3S$ $[M+H]^+$ 438.2097, found 438.2094.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-4-(cyclopropylethynyl)-9a-(4-nitrophenyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7f-major diast.):** Yellow solid. R_f = 0.55 (hexane/ethyl acetate 5:1). Melting point: 92-94 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 8.11–8.04 (m, 2H), 7.49–7.41 (m, 2H), 7.40 (dt, *J* = 7.6, 1.4 Hz, 1H), 7.20–7.12 (m, 1H), 6.93 (td, *J* = 7.8, 1.1 Hz, 1H), 6.86 (d, *J* = 7.8 Hz, 1H), 3.70–3.45 (m, 3H), 2.83–2.70 (m, 1H), 2.10–1.96 (m, 1H), 1.70–1.53 (m, 1H), 1.30–0.94 (m, 10H), 0.86–0.75 (m, 2H), 0.70–0.62 (m, 2H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.4, 152.1, 151.2, 147.7, 129.0, 128.4, 126.5, 123.6, 122.1, 121.3, 116.9, 94.5, 88.5, 80.9, 72.3, 53.0, 47.0, 28.4, 28.3, 23.8, 8.4, 8.3, 0.07. HMRS: calculated for $C_{27}H_{28}N_2NaO_5$ $[M+Na]^+$ 483.1849, found 483.1890.

***tert*-Butyl (3a*R**,4*S**,9a*R**)-9a-[4-(trifluoromethyl)phenyl]-4-[(trimethylsilyl)ethynyl]-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7g-major diast.):** White solid. R_f = 0.64 (hexane/ethyl acetate 5:1). Melting point: 106-108 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.61–7.57 (m, 2H), 7.53–7.46 (m, 3H), 7.30–7.24 (m, 1H), 7.03 (td, *J* = 7.4, 0.9 Hz, 1H), 6.97 (d, *J* = 8.1 Hz, 1H), 3.78–3.69 (m, 2H), 3.63 (td, *J* = 10.5, 7.2 Hz, 1H), 2.97–2.85 (m, 1H), 2.20–2.07 (m, 1H), 1.75–1.70 (m, 1H), 1.20 (s, 9H), 0.20 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.6, 152.4, 147.9, 130.2 (q, J_{CF} = 33.8 Hz), 129.1, 128.4, 127.1 (q, J_{CF} = 271.0 Hz), 126.0, 125.4, 121.9, 120.3, 116.9, 103.7, 94.5, 89.6, 80.6, 52.4, 46.9, 29.2, 28.2, 23.6, 0.2. ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) −62.5. HMRS: calculated for $C_{28}H_{32}F_3NNaO_3Si$ $[M+Na]^+$ 538.1995, found 538.1997.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-9a-[4-(trifluoromethyl)phenyl]-4-[(trimethylsilyl)ethynyl]-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7g-minor diast.):** White solid. R_f = 0.55 (hexane/ethyl acetate 5:1). Melting point: 240-242 °C. ^{1}H RMN (400 MHz, 330K, $CDCl_3$): δ (ppm) 8.26–8.19 (m, 4H), 8.02–7.93 (m, 2H), 7.75 (d, *J* = 8.5 Hz, 1H), 7.70 (t, *J* = 7.4 Hz, 1H), 4.49 (d, *J* = 2.5 Hz, 1H), 4.46–4.33 (m, 2H), 3.68 (app t, *J* = 7.5 Hz, 1H), 2.83–2.72 (m, 1H), 2.61–2.46 (m, 1H), 1.89 (s, 9H), 0.62 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.6, 152.2, 147.9, 129.9 (q, J_{CF} = 271.0 Hz), 129.8, 129.2, 126.8, 125.0, 124.6 (q, J_{CF} = 271.0 Hz), 122.0, 120.2, 117.5, 105.3, 93.6, 87.5, 80.6, 52.2, 46.4, 30.6, 28.2, 27.2, 0.1. ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) −62.3. HMRS: calculated for $C_{28}H_{32}F_3NNaO_3Si$ $[M+Na]^+$ 538.1995, found 538.2006.

***tert*-Butyl (3a*R**,4*R**,9a*R**)-4-(cyclohex-1-en-1-ylethynyl)-9a-(*p*-tolyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7h-major diast.):** Yellow solid. R_f = 0.38 (hexane/ethyl acetate 6:1). Melting point: 96-99 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.50 (d, *J* = 7.6 Hz, 1H), 7.26–7.21 (m, 3H), 7.12 (d, *J* = 8.5 Hz, 2H), 6.99–6.96 (m, 2H), 6.12–6.07 (m, 1H), 3.88 (d, *J* = 4.7 Hz, 1H), 3.73 (app t, *J* = 9.4 Hz, 1H), 3.61 (td, *J* = 10.5, 7.0 Hz, 1H), 2.96–2.82 (m, 1H), 2.35 (s, 3H), 2.20–2.03 (m, 5H), 1.72–1.56 (m, 5H), 1.20 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.7, 152.5, 140.6, 136.8, 134.3, 128.7, 128.5, 128.1, 125.1, 121.1, 120.8, 120.6, 116.5, 94.7, 86.1, 84.4, 79.8, 52.5, 46.6, 29.5, 28.5, 28.0, 25.5, 23.3, 22.3, 21.5, 20.8. HMRS: calculated for $C_{31}H_{36}NO_3$ $[M+H]^+$ 470.2689, found 470.2683.

***tert*-Butyl (3a*R**,4*S**,9a*R**)-4-(cyclohex-1-en-1-ylethynyl)-9a-(*p*-tolyl)-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7h-minor diast.):** Yellow solid. R_f = 0.34 (hexane/ethyl acetate 6:1). Melting point: 192-194 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.31–7.20 (m, 4H), 7.09–7.02 (m, 3H), 6.96 (td, *J* = 7.4, 1.2 Hz, 1H), 5.70–5.64 (m, 1H), 3.82 (d, *J* = 3.6 Hz, 1H), 3.78–3.64 (m, 2H), 2.89 (ddd, *J* = 10.2, 6.7, 3.7 Hz, 1H), 2.31 (s, 3H), 2.14–2.01 (m, 1H), 1.98 (bs, 2H), 1.84–1.80 (m, 1H), 1.76 (bs, 2H), 1.55–1.46 (m, 4H), 1.21 (s, 9H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 153.7, 152.5, 140.6, 136.4, 133.7, 129.3, 128.6, 128.3, 125.8, 121.3, 121.0, 120.5, 117.2, 94.2, 86.3, 84.7, 79.8, 52.3,

46.0, 30.1, 29.0, 28.0, 26.6, 25.5, 22.3, 21.5, 20.1. HMRS: calculated for $C_{31}H_{36}NO_3$ $[M+H]^+$ 470.2689, found 470.2682.

Methyl (3a*R,4*R**,9a*R**)-9a-(4-bromophenyl)-4-[(4-methoxyphenyl)ethynyl]-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7i-major diast.):** Yellow solid. R_f = 0.41 (hexane/ethyl acetate 5:1). Melting point: 93-95 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.50 (d, *J* = 7.6 Hz, 1H), 7.38 (d, *J* = 8.7 Hz, 2H), 7.28 (d, *J* = 8.8 Hz, 2H), 7.21–7.14 (m, 3H), 6.97–6.90 (m, 2H), 6.75 (d, *J* = 8.8 Hz, 2H), 3.88 (d, *J* = 4.7 Hz, 1H), 3.72 (s, 3H), 3.70–3.65 (m, 1H), 3.58 (td, *J* = 10.5, 7.1 Hz, 1H), 3.48 (s, 3H), 2.86 (ddd, *J* = 12.0, 7.0, 4.8 Hz, 1H), 2.19–2.06 (m, 1H), 1.79–1.65 (m, 1H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 160.0, 154.9, 152.2, 141.9, 133.3, 131.8, 129.1, 128.5, 127.2, 122.1, 121.9, 120.6, 117.0, 115.3, 114.3, 94.8, 85.5, 84.7, 55.5, 52.5, 52.3, 47.2, 28.8, 23.9. HMRS: calculated for $C_{28}H_{24}BrNNaO_4$ $[M+Na]^+$ 540.0780, found 540.0792.

Methyl (3a*R,4*S**,9a*R**)-9a-(4-bromophenyl)-4-[(4-methoxyphenyl)ethynyl]-2,3,3a,9a-tetrahydrochromeno[2,3-*b*]pyrrole-1(4*H*)-carboxylate (7i-minor diast.):** Yellow solid. R_f = 0.30 (hexane/ethyl acetate 5:1). Melting point: 75-77 °C. ^{1}H NMR (400 MHz, 330K, $CDCl_3$): δ (ppm) 7.29 (d, *J* = 8.8 Hz, 2H), 7.25–7.20 (m, 3H), 7.20–7.15 (m, 1H), 7.00 (d, *J* = 8.3 Hz, 1H), 6.90 (td, *J* = 7.5, 1.2 Hz, 1H), 6.82 (d, *J* = 8.9 Hz, 2H), 6.65 (d, *J* = 8.9 Hz, 2H), 3.85 (d, *J* = 2.8 Hz, 1H), 3.81–3.59 (m, 5H), 3.48 (s, 3H), 3.00–2.88 (m, 1H), 2.08–1.98 (m, 1H), 1.88–1.74 (m, 1H). ^{13}C NMR (100 MHz, 330K, $CDCl_3$): δ (ppm) 159.6, 152.1, 142.0, 133.1, 131.3, 129.9, 129.2, 128.1, 122.0, 120.3, 117.6, 115.3, 114.1, 93.9, 87.6, 83.5, 55.4, 52.4, 51.9, 46.6, 30.0, 27.1. HMRS: calculated for $C_{28}H_{24}BrNNaO_4$ $[M+Na]^+$ 540.0780, found 540.0786.

(3a*R,4*R**,9a*R**)-9a-(4-bromophenyl)-4-[(4-methoxyphenyl)ethynyl]-1-tosyl-1,2,3,3a,4,9a-hexahydrochromeno[2,3-*b*]pyrrole (7j-major diast.):** Orange solid. R_f = 0.26 (hexane/ethyl acetate 7:1). Melting point: 170-172 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.80 (d, *J* = 8.2 Hz, 2H), 7.74 (d, *J* = 8.7 Hz, 1H), 7.5 –7.44 (m, 2H), 7.38 (d, *J* = 8.7 Hz, 2H), 7.35–7.28 (m, 4H), 7.20 (t, *J* = 7.6 Hz, 1H), 6.97 (app t, *J* = 7.0 Hz, 1H), 6.82 (d, *J* = 8.8 Hz, 2H), 6.67 (d, *J* = 7.6 Hz, 1H), 3.84–3.71 (m, 5H), 3.51 (t, *J* = 9.6 Hz, 1H), 3.09–2.95 (m, 1H), 2.46 (s, 3H), 2.29–2.16 (m, 1H), 1.74–1.60 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm) 159.6, 151.5, 143.6, 140.0, 136.5, 133.1, 131.5, 129.8, 129.1, 128.6, 127.9, 127.1, 122.5, 121.7, 119.1, 115.7, 114.8, 113.9, 96.6, 85.0, 84.1, 55.3, 51.3, 47.8, 28.1, 23.5, 21.6. HMRS: calculated for $C_{33}H_{29}BrNO_4S$ $[M+H]^+$ 614.0995, found 614.0972.

(3a*R,4*S**,9a*R**)-9a-(4-bromophenyl)-4-[(4-methoxyphenyl)ethynyl]-1-tosyl-1,2,3,3a,4,9a-hexahydrochromeno[2,3-*b*]pyrrole (7j-minor diast.):** Orange solid. R_f = 0.11 (hexane/ethyl acetate 7:1). Melting point: 184-186 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.82 (d, *J* = 8.3 Hz, 2H), 7.56–7.48 (m, 3H), 7.41 (d, *J* = 8.7 Hz, 2H), 7.37–7.31 (m, 4H), 7.22 (app t, *J* = 7.8 Hz, 1H), 6.99 (app t, *J* = 7.0 Hz, 1H), 6.84 (d, *J* = 8.8 Hz, 2H), 6.69 (d, *J* = 7.4 Hz, 1H), 3.82–3.79 (m, 5H), 3.53 (app t, *J* = 8.9 Hz, 1H), 3.12–2.96 (m, 1H), 2.48 (s, 3H), 2.26–2.16 (m, 1H), 1.81–1.64 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ (ppm) 159.6, 151.5, 143.5, 140.0, 136.6, 133.1, 131.5, 129.1, 128.9, 128.6, 127.9, 122.5, 121.7, 119.2, 115.7, 114.8, 113.9, 96.6, 85.0, 84.2, 55.3, 51.4, 47.9, 28.1, 23.5, 21.6. HMRS: calculated for $C_{33}H_{28}BrNNaO_4S$ $[M+Na]^+$ 636.0814, found 636.0812.

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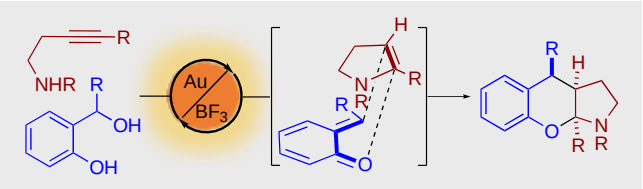

A gold / BF_3 catalytic system promotes the transformation of simple 3-butynamines and 2-(hydroxymethyl)phenol derivatives into cyclic enamines and *ortho*-quinone methide derivatives. The subsequent formal [4+2]-cyclization reaction between these two intermediates gives rise to hexahydrochromeno[2,3-*b*]pyrrole derivatives.

Binary Catalysis

Patricia Fernández, Pedro Alonso, Francisco J. Fañanás, and Félix Rodríguez**

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Simultaneous Generation and Subsequent Cycloaddition of *ortho*-Quinonemethides and Cyclic Enecarbamates Promoted by a Gold / Lewis Acid Catalytic System