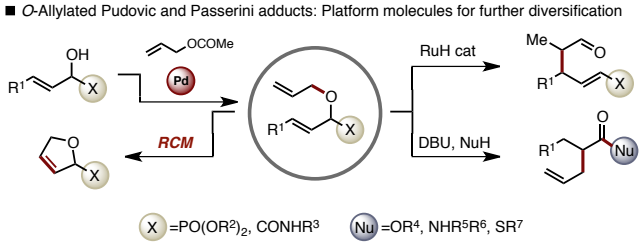
O-Allylated Pudovik and Passerini Adducts as Versatile Scaffolds for Product Diversification

Mansour Dolé Kerim,[‡] Tania Katsina,[†] Martin Cattoen,[†] Nicolas Fincias,[‡,†] Stellios Arseniyadis,[†,*] and Laurent El Kaïm[‡,*]

[‡] Laboratoire de Synthèse Organique, CNRS, Ecole Polytechnique, ENSTA ParisTech, UMR 7652, Université Paris-Saclay, 828 Bd des Maréchaux, 91128 Palaiseau (France)

[†] Queen Mary University of London, School of Biological and Chemical Sciences, Mile End Road, London, E1 4NS (UK)



ABSTRACT: The palladium-catalyzed *O*-allylation of α-hydroxyphosphonates and α-hydroxyamides obtained from Pudovik and Passerini multicomponent reactions has allowed an interesting and highly straightforward access to a variety of building blocks for product diversification. These post-functionalizations include a selective base- or ruthenium hydride-mediated isomerization/Claisen rearrangement cascade and a ring-closing metathesis that allows access to a variety of diversely functionalized phosphono-oxaheterocycles.

INTRODUCTION

For several decades now, metal-catalyzed reactions have become an increasingly important subset of synthetic tools to assemble molecules. Among them, the palladium-catalyzed allylic alkylation, also referred to as the Tsuji-Trost reaction, has been recognized as an essential tool for the construction of C–C bonds. Indeed, this reaction allows to easily incorporate an allyl group onto an *in situ* generated *C*-centered nucleophile under mild conditions.[1] Another interesting application is the construction of C–O bonds, however this approach has been much less explored.[2,3] In our quest to implement the palladium-catalyzed allylic alkylation to new substrates,[4] we became interested in applying this chemistry to α-hydroxyphosphonates, also known as Pudovik adducts (Figure 1). Indeed, we were intrigued by the possibility of the alkoxide intermediate to undergo either a direct *O*-allylation or a competing *C*-allylation resulting from a preliminary phospha-Brook rearrangement that is know to occur under basic conditions, and which would afford a mixture of *C*- and *O*-allylated products. Our seminal investigation led to the conclusion that the phospha-Brook rearrangement did not occur under the palladium conditions and that the *O*-allylation product was formed exclusively, thus offering an interesting solution to an unaddressed synthetic challenge, namely the alkylation of α-hydroxyphosphonates.[5] Since then, we have applied this palladium-catalyzed *O*-allylation to a wider range

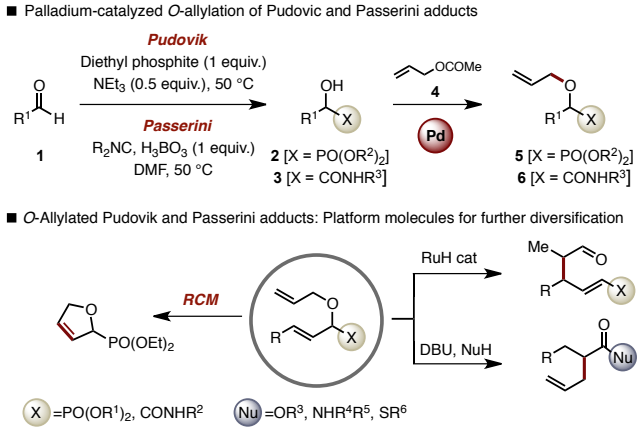


Figure 1. *O*-Allylated Passerini and Pudovik adducts: Useful platforms for product diversification.

of α-hydroxyphosphonate derivatives and eventually extended the method to yet another interesting family of compounds, namely α-hydroxyamides, also referred to as Passerini adducts. In addition, we have showcased the synthetic utility of the resulting products by subjecting them to various key post-transformations as a mean to access valuable building blocks. We report here in full the results of our efforts.

RESULTS AND DISCUSSION

To begin this endeavour, a first α-hydroxyphosphonate (**2a**) was synthesized using standard Pudovik conditions [diethyl phosphite (1 equiv.), NEt_3 (0.5 equiv.), 50 °C, 24 h] and subjected to slightly optimized palladium-catalyzed allylic alkylation conditions [Pd_2dba_3 (2.5 mol %), PPh_3 (10 mol %), Cs_2CO_3 (0.25 equiv.), toluene, 50 °C, 30 min] using allyl methyl carbonate as an allyl donor (Scheme 1). Interestingly, the *C*-allylated product was not observed, but instead the reactions led to the formation of the corresponding *O*-allylated product **5a**. Considering the difficulty in making this type of compounds under more traditional alkylating conditions which favor the phospha-Brook rearrangement, we decided to further investigate this reaction.A set of diversely substituted α-hydroxyphosphonates were therefore synthesized. As a general trend, all the Pudovik adducts (**2a-q**) were obtained in excellent yields after simple evaporation and filtration over a pad of silica gel to remove any traces of phosphite, which were found to inhibit the subsequent allylation step. The reaction proved to be compatible with different phosphites (**2a-c)** as well as a wide range of aldehydes, including aromatic (**2a-g**) and α,β-unsaturated aldehydes (**2p-r**), albeit some phosphonates were obtained in slightly lower yields such as the heteroaromatic (**2h-n**) and the aliphatic derivatives (**2o**). Going forward, the conditions established for the allylation of **2a** efficiently provided a set of structurally diverse α-allyloxyphosphonates. The influence of the phosphite was minimal, though the smaller dimethyl phosphite **5b** was obtained in a slightly higher yield (94%) than the diethyl and diisopropyl analogues **5a** (90%) and **5c** (90%). Both electron-rich and electron-poor aryls substituents were well-tolerated (78-97% yield, **5a-g**). Similarly, heteroaryl-containing substrates also led to high yields (71-98% yield, **5h-n**), although the formation of the 3-pyridyl derivative **5h** required a longer reaction time (12 h *vs* 30 min). This lower reactivity was also observed with the aliphatic precursor **2o**, which required a slightly higher temperature (100 °C) to generate the desired product **5o** (67%). The influence of the allyl moiety was also evaluated. Interestingly, while the use of the branched methallyl carbonate did not hamper the reaction (**5s**, 88%), we observed slightly lower yields when using the linear cinnamyl carbonate instead (60-64% for **5t** and **5u** *vs* 85-96% for **5g** and **5i**). Finally, the more hindered quaternary α-hydroxyphosphonates **2s** and **2t** derived from the corresponding methyl ketone precursors[6] led to the α-allylated products **5v** and **5w**, albeit in 27% and 21% yield respectively.

To extend the scope of the palladium-catalyzed allylic alkylation, we next turned our attention towards a related family of compounds, namely α-hydroxyamides. The latter were prepared *via* a Passerini multicomponent reaction by reacting various cinnamaldehydes with the corresponding isocyanate in the presence of boric acid.[7] The resulting Passerini adducts were then subjected to the same allylic alkylation conditions as previously with the exception that Cs_2CO_3 was not used as it appeared to be unnecessary. To our delight, the corresponding *O*-allylated products **6a-e** were all obtained in high yields ranging from 77 to 84%.

With these *O*-allylated products in hand, we next set out to demonstrate their synthetic utility by running several diversifications.

The first one that came into our mind involved the *O*-allylated cinnamyl derivatives **5p-r** and **6a-d**. Indeed, these two families of bis-allyl ethers have in common a relatively acidic allylic proton, with the styryl group further activating the electron-withdrawing character of the amide and the phosphonate, as well as an allylic position that can potentially be activated by a metal. As such, a base-mediated process would trigger an isomerization of the cinnamyl double bond,[8] while a ruthenium-,[9,10] rhodium[11] or iridium-based[12] catalyst would selectively promote the isomerization of the other non styrenyl double bond. In both cases, the resulting allyl vinyl ethers can undergo subsequent Claisen rearrangement to generate two very different 1,4-alkenyl carbonyl derivatives *via* a chair-like transition state (Schemes 2 and 4).[13] This one-pot 1,2-H isomerization/Claisen rearrangement sequences have been repeatedly implemented to build structurally complex products from simpler, more accessible diallyl ethers,[14] however, this strategy is not without challenges as both double bonds are susceptible to isomerization, resulting in possible mixtures.

With this in mind, we first started by evaluating the base-mediated isomerization/Claisen rearrangement cascade on the *O*-allylated Passerini adducts **6a-d**. The results are depicted in Scheme 3. When *O*-allylamide **6a** was heated in the presence of triethylamine or Cs_2CO_3 and toluene at 120 °C under microwave irradiation, unreacted starting material was recovered. Interestingly, switching to DBU (0.5 equiv.) under otherwise identical conditions led to the desired α-ketoamide **7a** in 65% yield.[8] These conditions were eventually applied to the allyloxy amides **6b-d** affording the desired α-ketoamides **7b-d** in 76-88% yield (Scheme 2).

This DBU-mediated isomerization was eventually applied to the Pudovik adducts **5p-r**. To our surprise, when the corresponding phosphonate ethers were exposed to our optimized conditions, intractable mixtures of products were obtained. Replacing toluene with acetonitrile or DMF did not improve the result. In an effort to analyze the potential issues associated with the formation of α-ketophosphonates under these conditions, we reasoned that the latter could potentially be decomposing under basic conditions or even undergo ketene formation. Indeed, ketophosphonates are known for their behavior as acylating agents with the phosphonyl group being easily displaced by various nucleophiles. To validate our hypothesis, we ran the reactions in the presence of various primary amines. To our delight, the corresponding amides **9a-d** were formed, albeit in moderate yields ranging from 56 to 77%. Piperidine was found to be less reactive affording amide **9e** in only 38% isolated yield. NH indoles could also be used as showcased by the formation of the acylated indoles **9f-g**. Unfortunately, attempts to direct the reaction towards *C*-acylated indoles using *N*-methyindole led to unidentified mixtures. The reaction can also be run in a nucleophilic solvent such as ethanol or trifluoroethanol to afford the corresponding esters **9i** and **9j** in 89% and 53% yields respectively. The reaction was eventually extended to the formation of thioesters by running the reaction in a 2:1 toluene/thiol solution and heating at 150 °C under microwave irradiation; the corresponded thioester **9k** was formed in 67% yield (Scheme 3).

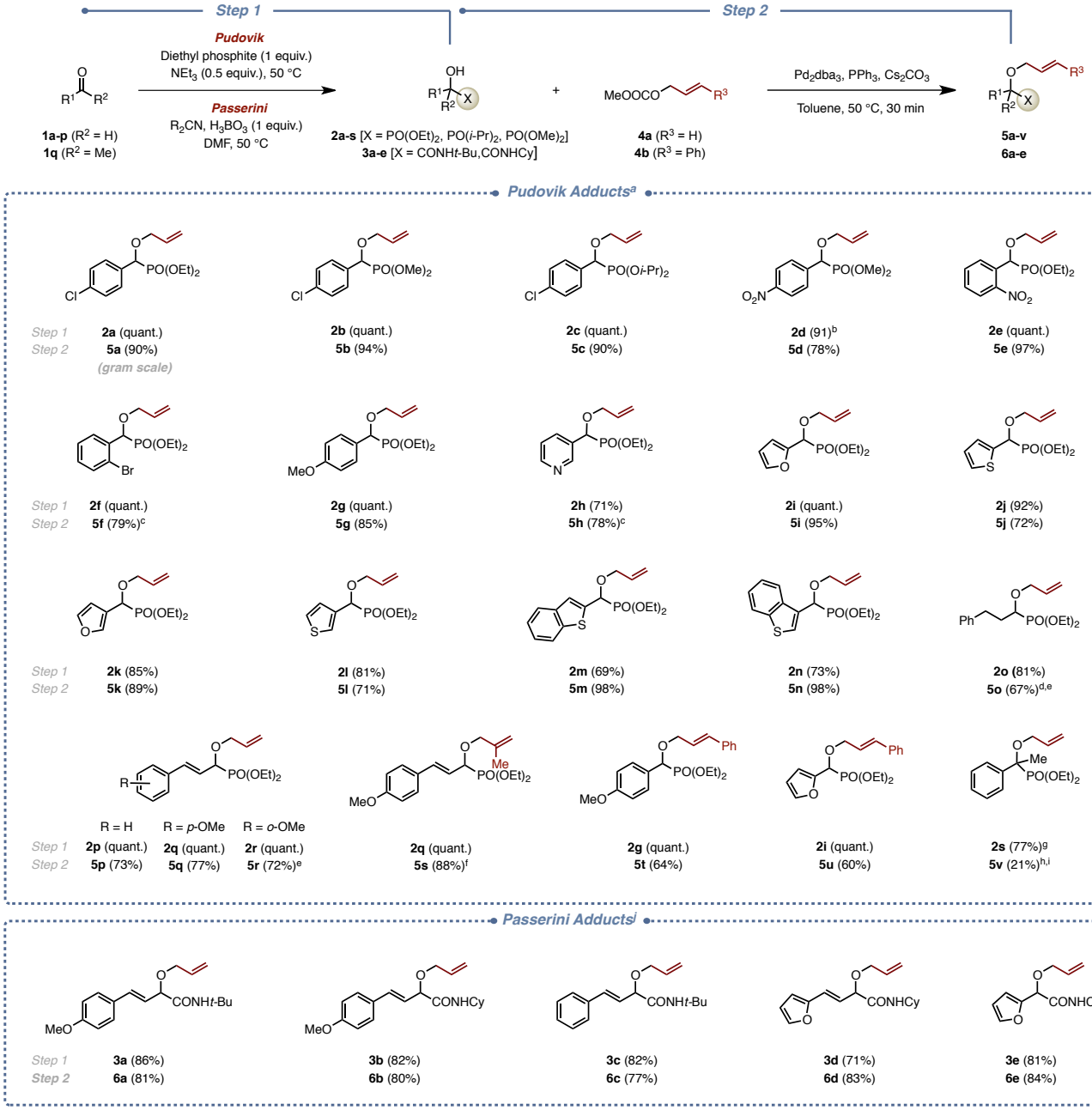
Having prepared a number of α,α-diallyloxyphosphonates, we then evaluated the possibility of reorganizing their structure using a metal-catalyzed approach.[15] Treating **5q** with $RuClH(CO)(PPh_3)_3$ in toluene under microwave irradiation (120 °C, 30 min) led to the formation of the Claisen rearrangement product **10a** in 41% yield and a 2:1 diastereomeric ratio (Scheme 4). We then applied our initial

reaction conditions [$RuClH(CO)(PPh_3)_3$ (5 mol %), 120 °C (MW), toluene, 30 min] to the *O*-allyl Passerini adducts **6a-c**. The latter were readily converted to the corresponding α,β-unsaturated amides **10b-d** in moderate to good yields ranging from 69 to 85% albeit in a roughly 1:1 mixture of diastereoisomers.

When the ruthenium-catalyzed isomerization conditions were applied to compound **5i**, we observed the formation of the disubstituted heterocycle **11a**. After slightly optimizing the reaction conditions (reaction run in chloroform at 180 °C for 10 min under microwave irradiation), we were able to increase the yield to 62% (Scheme 5). These conditions were eventually applied to a series of heterocyclic *O*-allylated derivatives (**5j-n** and **6e**), resulting in the formation of the corresponding disubstituted heterocycles **11b-g** in yields ranging from 29 to 62%. The conditions were also applied to the quinoline derivative **5x** (structure not shown), affording the disubstituted quinoline **11h** in 45% yield.

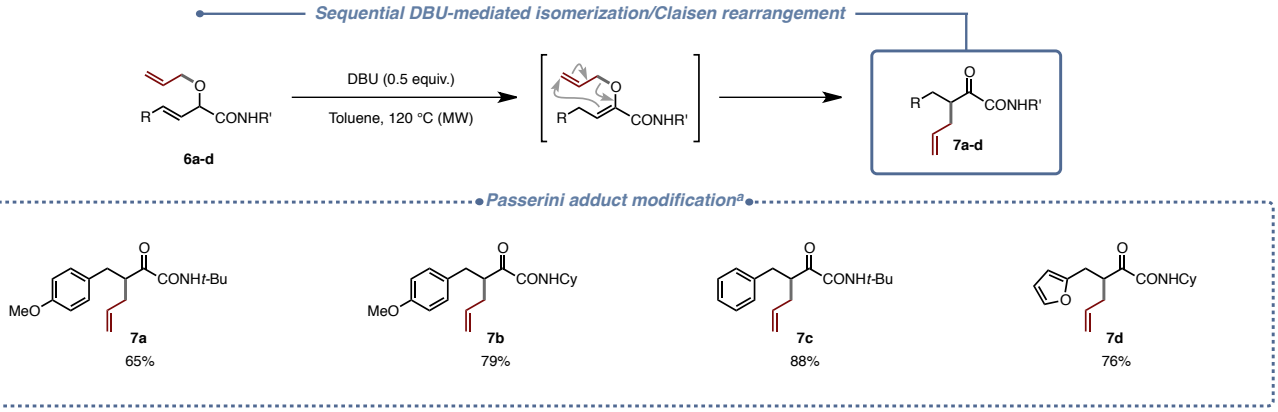
Finally, we turned our attention to the synthesis of phosphono-oxaheterocycles by subjecting various Pudovik adducts bearing a pendent olefin to ring-closing metathesis (RCM) conditions (Scheme 6).[16] To this end, we prepared

Scheme 1. Sequential DBU-mediated isomerization/Claisen rearrangement.



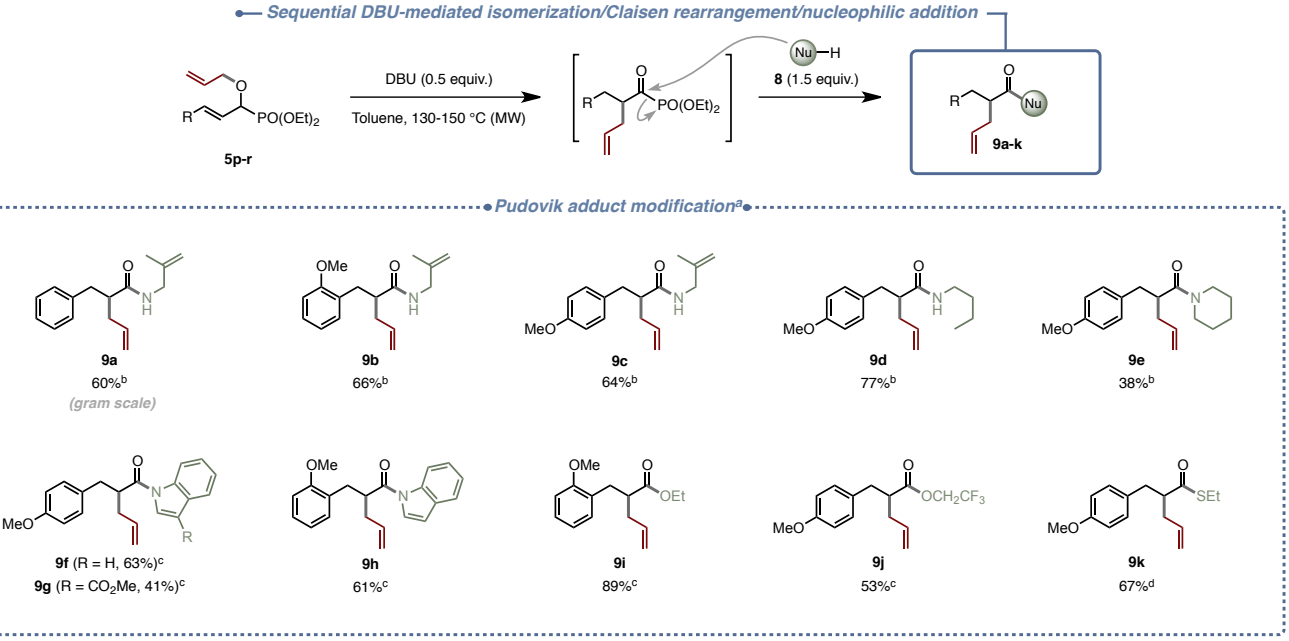
[a] All the reactions were run on a 1 mmol scale (yields reported are isolated yields). [b] Reaction run under mechanical stirring. [c] Reaction ran at 50 °C for 2 h (**5f**) and 12 h (**5h**). [d] Reaction ran at 100 °C. [e] Reaction ran for 1.5 h. [f] Reaction ran for 2 h. [g] Prepared from acetophenone. [h] 50% starting ketone recovered. [i] Reaction ran for 1 h in the absence of Cs_2CO_3. [j] All the reactions were run on a 5 mmol scale.

Scheme 2. Sequential DBU-mediated isomerization/Claisen rearrangement.



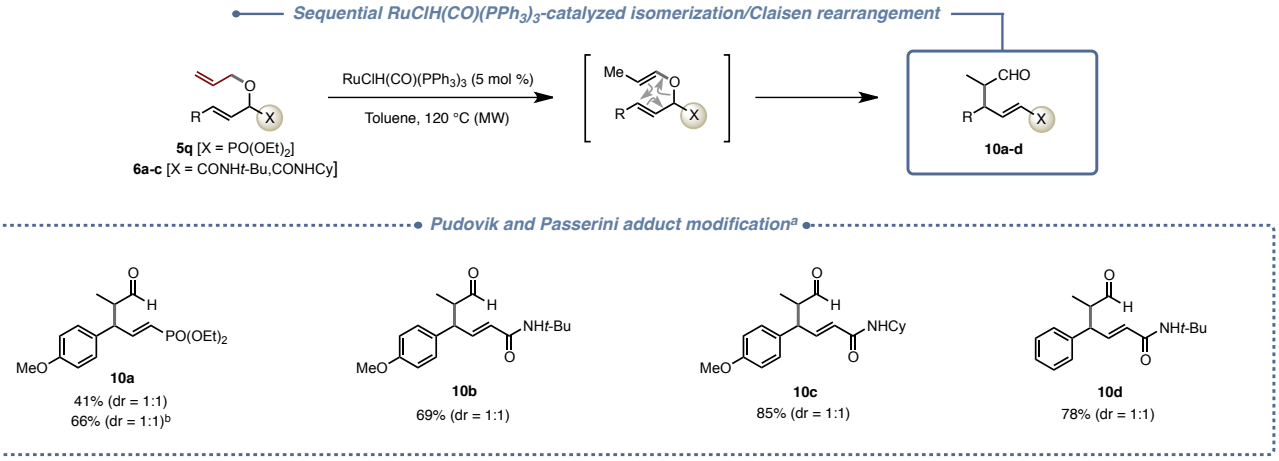
All the reactions were run on a 0.5 mmol scale. [a] Yields reported are isolated yields.

Scheme 3. Sequential DBU-mediated isomerization/Claisen rearrangement.



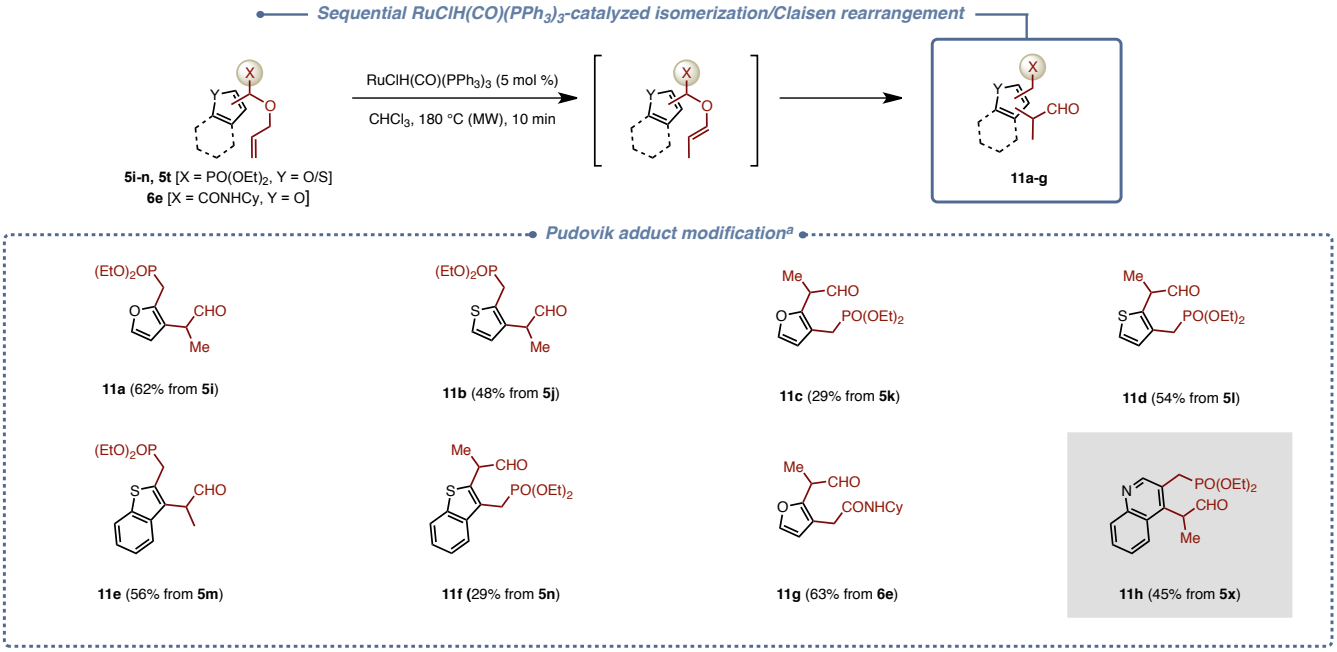
All the reactions were run on a 0.5 mmol scale. [a] Yields reported are isolated yields. [b] Reaction ran at 130 °C. [c] Reaction ran at 140 °C. [d] Reaction ran at 150 °C.

Scheme 4. Sequential Ru-catalyzed isomerization/Claisen rearrangement.



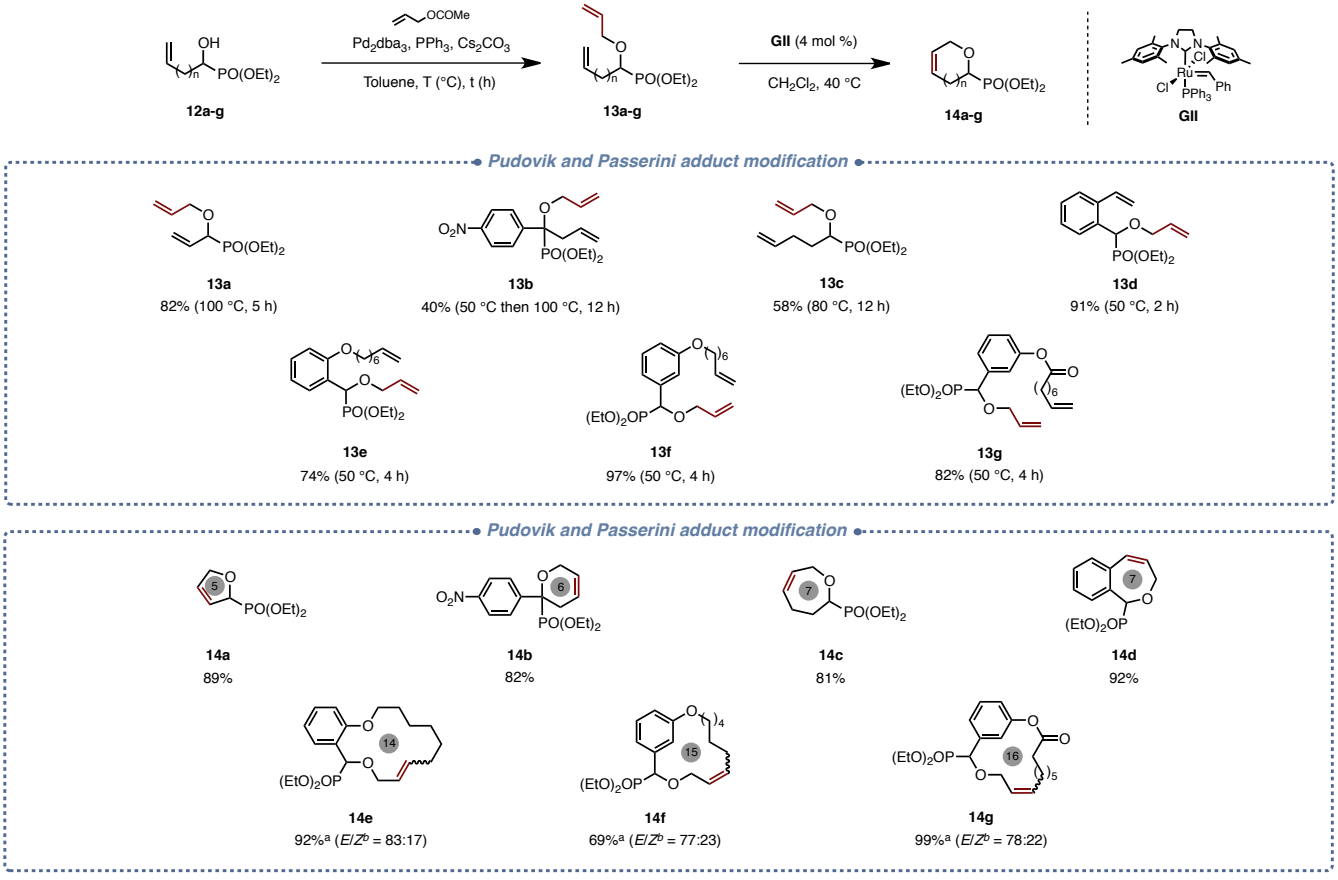
All the reactions were run on a 0.5 mmol scale. [a] Yields reported are isolated yields). [b] Reaction run in DMF at 140 °C

Scheme 5. Pudovik and Passerini adduct modification: Sequential Ru-catalyzed isomerization/Claisen rearrangement.



All the reactions were run on a 0.1 mmol scale. [a] Yields reported are isolated yields.

Scheme 6. Pudovik adduct modification: Sequential *O*-allylation/RCM.



All the reactions were run on a 1 mmol scale (yields reported are isolated yields). [a]Required 6 mol % catalyst loading. [b]Determined by NMR analysis on the crude reaction mixture.

a range of dienes of various length **13a-g** and subjected them to standard RCM conditions using Grubbs' second-generation catalyst, **GII** (4 mol %) in refluxing CH_2Cl_2 (100 mM concentration). Under these conditions, the smaller rings, such as the dihydrofuran **14a** (89%), the dihydropyrane **14b** (82%) and the oxepin **14c** (81%) were obtained in high yields. Benzooxepin **14d** was obtained with an even higher yield of 92%. The larger derivatives such as the 14-, 15- and 16-phosphono-oxaheterocycles could also be effectively accessed, however they required more dilute conditions (1 mM) to avoid any undesired oligomerization. Of note is the efficient formation of [12] and [13]metacyclophanes **14f** and **14g** which were obtained in 69 and 99% yield, respectively. All three macrocycles were obtained as a mixture of *E*/*Z* isomers in a consistent ratio of 4:1 as assessed by ^{13}C NMR. This selectivity is in agreement with previous results observed with the widely available Grubbs' second-generation catalyst.[17]

CONCLUSION

In summary, we have developed orthogonal catalytic conditions for a cascade isomerization/Claisen rearrangement starting from *O*-allyl Pudovik and Passerini adducts. The presence of the amido or phosphono substituents is highly beneficial as it increases the acidity of the starting materials thus allowing a more efficient isomerization/Claisen cascade under basic conditions. The applicability of the method is further demonstrated by trapping the acylphosphonate intermediates of Pudovik adducts with various oxygen or nitrogen nucleophiles, allowing to access diverse compounds. A switch in the selectivity of the isomerization was achieved when a ruthenium hydride catalyst was used.

EXPERIMENTAL SECTION

General methods. All reactions were carried out in sealed tubes. Column chromatography was carried out on silica gel. ^1H NMR spectra were obtained with tetramethylsilane ($\delta = 0$ ppm) as an internal standard in $CDCl_3$ using a Bruker AVANCE 400 spectrometer (400 MHz). Data are reported as follows: chemical shift in ppm, apparent multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, p = pentet, m = multiplet or overlap of non-equivalent resonances), coupling constants, integration. ^{13}C NMR spectra were recorded at 100 MHz and residual solvent peaks were used as an internal reference ($CHCl_3$ δ 77.16). Data are reported as follows: chemical shift in ppm, multiplicity deduced from DEPT experiments (CH_3, CH_2, CH, C_q), apparent multiplicity, coupling constants and integration where relevant. IR spectra were recorded on a Perkin Elmer Spectrum 65 FT-IR Spectrometer. Melting points were measured on a Stuart SMP3 melting point apparatus and are uncorrected. Low-resolution mass spectra were recorded on an Agilent 1100 series LC-MS (with a 6310 ion trap) under electrospray ionization (ESI). For compounds containing bromine, the mass of ^{79}Br was used. All commercially available compounds were used without further purification. Compounds **2a-l**, **2o-r, 2t**, **5a-i**, **5o**, **5q**, **5t-u**, **5w**, **12a-g**, **13a-g** and **14a-g** have already been reported and therefore won't be described here; the spectral data matched those reported in the literature. Compounds **2r** and **2u** were prepared and engaged in the allylation step without further purification.

General procedure for the synthesis of the α-hydroxyphosphonates. A mixture of aldehyde (1.01 equiv.), diethyl phosphite (1.00 equiv.) and triethylamine (0.50 equiv.) was stirred at room temperature or 50 °C for the indicated time. The reaction mixture was then diluted with chloroform and concentrated under reduced pressure to remove NEt_3.

Dimethyl [hydroxy(4-nitrophenyl)methyl]phosphonate (2d). Compound **2d** was prepared by mechanically stirring 4-nitrobenzaldehyde (831 mg, 5.5 mmol, 1.1 equiv.), dimethylphosphite (0.46 mL, 5.0 mmol, 1.0 equiv.) and triethylamine (0.35 mL, 2.5 mmol, 0.5 equiv.). The title compound was obtained as an orange solid (1.2 g, 4.6 mmol, 91%) after a very fast reaction completed in five minutes and immediately purified by flash column chromatography over silica gel (CH_2Cl_2/EtOAc, 100:0 to 0:100). Spectral data matched those reported in the literature.[5] ^1H NMR (400 MHz, $CDCl_3$) δ 8.23 (d, J = 8.7 Hz, 2H), 7.67 (dd, J = 8.7, 2.2 Hz, 2H), 5.22 (d, J = 12.3 Hz, 1H), 4.79 (brs, 1H), 3.78 (d, J = 8.9 Hz, 3H), 3.75 (d, J = 9.0 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 147.8 (d, J = 3.7 Hz), 143.9, 127.7 (d, J = 5.3 Hz, 2C), 123.6 (d, J = 2.6 Hz, 2C), 70.1 (d, J = 158.6 Hz), 54.6 (d, J = 7.1 Hz), 53.9 (d, J = 7.6 Hz). IR (thin film): 3246, 2958, 2854, 1518, 1347, 1236, 1027, 864 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_9H_{12}NO_6P$ 261.0402; Found 261.0396.

Diethyl [(allyloxy)(benzo[b]thiophen-2-yl)methyl]phosphonate (2m). Colourless oil, 208 mg, 69X% isolated yield. R_f = 0.45 (PE/Et_2O = 1:5). ^1H NMR (400 MHz, $CDCl_3$) δ 7.82 (dd, J = 4.6, 3.9 Hz, 1H), 7.75 (dd, J = 8.4, 6.4 Hz, 1H), 7.42 (d, J = 3.4 Hz, 1H), 7.37-7.29 (m, 2H), 5.31 (ddd, J = 11.7, 5.5, 1.0 Hz, 1H), 4.22-4.10 (m, 4H), 3.29 (dd, J = 9.2, 5.5 Hz, 1H), 1.36-1.25 (m, 6H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 140.1 (dd, J = 15.4, 2.1 Hz), 124.6 (d, J = 9.2 Hz), 123.9, 122.8 (d, J = 8.2 Hz), 122.5, 67.9 (d, J = 164.3 Hz), 63.8 (d, J = 7.0 Hz), 63.8 (d, J = 10.6 Hz), 16.6. IR (thin film): 3250, 2985, 1439, 1205 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{13}H_{17}O_4PSNa$ 323.0483; Found 323.0506.

Diethyl [(allyloxy)(benzo[b]thiophen-3-yl)methyl]phosphonate (2n). Colorless oil, 218 mg, 73% isolated yield. R_f = 0.45 (PE/Et_2O = 1:5). ^1H NMR (400 MHz, $CDCl_3$) δ 7.93-7.89 (m, 1H), 7.88-7.84 (m, 1H), 7.74 (dd, J = 3.4, 0.5 Hz, 1H), 7.42-7.33 (m, 2H), 5.42 (ddd, J = 11.0, 5.8, 0.8 Hz, 1H), 4.17-3.86 (m, 4H), 3.70 (dd, J = 8.6, 5.8 Hz, 1H), 1.27 (tt, J = 2.3, 1.2 Hz, 3H), 1.14 (tt, J = 5.3, 2.7 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 140.5, 137.5 (d, J = 5.9 Hz), 131.8, 125.6 (d, J = 7.4 Hz), 124.7, 124.3, 122.8 (d, J = 16.2 Hz), 66.4 (d, J = 164.2 Hz), 63.5 (d, J = 7.1 Hz), 63.4 (d, J = 7.2 Hz), 16.5 (dd, J = 12.3, 5.6 Hz). IR (thin film): 3200, 2980, 1430, 1203 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{13}H_{17}O_4PSNa$ 323.0483; Found 323.0506.

Diethyl (1-hydroxy-1-phenyl)ethylphosphonate (2s). *n*-BuLi (as a 2.5 M solution in hexanes, 2.1 μL, 5.3 μmol) and diethyl phosphite (822 μL, 6.38 mmol, 1.2 equiv.) were mixed under dry nitrogen. The mixture was stirred for 5 min before acetophenone (0.62 mL, 5.0 mmol, 1.0 equiv.) was added at 0 °C. The resulting mixture was allowed to stir at the same temperature for 5 min and the reaction was quenched by addition of EtOAc (3 mL) and H_2O (2 mL). The layers were separated and the aqueous phase was extracted with EtOAc (2 x 5 mL). The combined organic phases were dried over anhydrous $MgSO_4$ and concentrated under reduced pressure. The crude residue was co-evaporated with toluene several times to remove traces of phosphite and purified by flash column chromatography over silica gel with a gradient of EtOAc in petroleum ether (50/50 to 70/30). The title compound **2s** was obtained as white crystals (1,3 g, 5.2 mmol, 98%). R_f = 0.31 (CH_2Cl_2/EtOAc = 7:3). mp = 77-78 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.63-7.58 (m, 2H), 7.35 (t,

J = 7.3 Hz, 2H), 7.28 (dd, J = 7.3, 1.7 Hz, 1H), 4.15-3.80 (m, 4H), 3.66 (brs, 1H, OH), 1.82 (d, J = 15.5 Hz, 3H), 1.25 (t, J = 7.1 Hz, 3H), 1.19 (t, J = 7.1 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 141.1, 128.1 (d, J = 2.5 Hz), 127.5 (d, J = 2.9 Hz), 126.0 (d, J = 4.3 Hz), 73.6 (d, J = 158.6 Hz), 63.4 (d, J = 4.3 Hz), 63.4 (d, J = 4.4 Hz), 26.1 (d, J = 3.9 Hz), 16.5 (d, J = 5.7 Hz), 16.4 (d, J = 6.0 Hz). IR (thin film): 3580, 3382, 2997, 2932, 1496, 1247, 970 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{12}H_{19}O_4P$ 258.1021; Found 258.1016.

General procedure for the synthesis of α-hydroxyamides (3a-e). A mixture of aldehyde (5 mmol), isocyanide (5 mmol) and boric acid (5 mmol) in DMF (1 mL) was stirred at 50 °C using a heating mantle for 24 h. The crude solution was then diluted with 100 mL of Et_2O and washed two times with 10 mL of water. After evaporation of the solvent under reduced pressure, the crude residue was purified by flash chromatography over silica gel.

(*E*)-*N*-(*tert*-Butyl)-2-hydroxy-4-(4-methoxyphenyl)but-3-enamide (3a). Yellow solid, 1.13 g, 86% isolated yield. R_f = 0.38 (PE/Et_2O = 3:7). mp = 135-137 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, J = 8.6 Hz, 2H), 6.84 (d, J = 8.6 Hz, 2H), 6.65 (d, J = 15.8 Hz, 1H), 6.10 (dd, J = 15.8, 7.1 Hz, 1H), 6.07 (brs, 1H), 4.54 (ddd, J = 7.1, 3.7, 1.0 Hz, 1H), 3.80 (s, 3H), 3.67 (brs, 1H), 1.36 (s, 9H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 171.4, 159.7, 133.1, 128.9, 128.1, 125.0, 114.1, 73.2, 55.4, 51.6, 28.8. IR (thin film): 3364, 2964, 2932, 2836, 1644, 1605, 1510, 1454, 1364, 1245, 1173, 1029, 978, 828, 788 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{15}H_{21}NO_3$ 263.1521; Found 263.1521.

(*E*)-*N*-Cyclohexyl-2-hydroxy-4-(4-methoxyphenyl)but-3-enamide (3b). Yellow solid, 1.18 g, 82% isolated yield. R_f = 0.23 (PE/Et_2O = 3:7). mp = 95-97 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.33 (d, J = 8.8 Hz, 2H), 6.86 (d, J = 8.8 Hz, 2H), 6.70 (d, J = 15.9 Hz, 1H), 6.50 (brs, 1H), 6.18 (dd, J = 15.9, 6.5 Hz, 1H), 4.69 (d, J = 6.5 Hz, 1H), 4.30 (br, 1H), 3.83 (s, 3H), 3.81-3.70 (m, 1H), 1.98-1.86 (m, 2H), 1.78-1.57 (m, 3H), 1.45-1.29 (m, 2H), 1.26-1.08 (m, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 171.5, 159.5, 132.3, 128.9, 128.0, 124.9, 114.0, 72.9, 55.3, 48.4, 33.0, 25.5, 24.8. IR (thin film): 3393, 3052, 2934, 2856, 1645, 1607, 1511, 1264, 1249, 1174, 1033, 825, 732 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{23}NO_3$ 289.1678; Found 289.1685.

(*E*)-*N*-(*tert*-Butyl)-2-hydroxy-4-phenylbut-3-enamide (3c). Yellow solid, 961 mg, 82% isolated yield. R_f = 0.30 (PE/Et_2O = 4:6). mp = 95-97 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.35-7.29 (m, 2H), 7.28-7.16 (m, 3H), 6.65 (dd, J = 15.9, 0.8 Hz, 1H), 6.19 (dd, J = 15.9, 6.9 Hz, 1H), 6.01 (brs, 1H), 4.51 (dd, J = 6.9, 2.6 Hz, 1H), 3.61 (brs, 1H), 1.29 (s, 9H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 171.1, 136.1, 133.4, 128.7, 128.3, 127.3, 126.9, 73.1, 51.6, 28.9. IR (thin film): 3384, 3055, 2970, 1658, 1649, 1525, 1454, 1366, 1264, 1223, 966, 909, 732 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{14}H_{19}NO_2$ 233.1416; Found 233.1409.

(*E*)-*N*-Cyclohexyl-4-(furan-2yl)-2-hydroxybut-3-enamide (3d). Red oil 887 mg, 71% isolated yield. R_f = 0.33 (PE/Et_2O = 2:8). ^1H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, J = 1.8 Hz, 1H), 6.55 (dd, J = 15.8, 1.4 Hz, 1H), 6.44 (br, 1H), 6.34 (dd, J = 3.3, 1.8 Hz, 1H), 6.29-6.13 (m, 2H), 4.64 (brs, 1H), 4.13 (br, 1H), 3.87-3.46 (m, 1H), 1.95-1.81 (m, 2H), 1.75-1.05 (m, 3H), 1.40-1.24 (m, 2H), 1.22-1.02 (m, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 171.1, 152.0, 142.4, 125.7, 120.7, 111.5, 109.0, 72.4, 48.5, 33.0, 25.5, 24.9. IR (thin film): 3302, 2964, 2932, 2855, 1642, 1526, 1450, 1264, 1013, 959, 731, 702 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{14}H_{19}NO_3$ 249.1365; Found 249.1622.

***N*-Cyclohexyl-4-(furan-2yl)-2-hydroxyacetamide (3e).** Brown solid, 910 mg, 81% isolated yield. R_f = 0.3 (PE/Et_2O = 2:8). mp = 85-87 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.36 (dd, J = 1.8, 0.8 Hz, 1H), 6.42 (br, 1H), 6.33-6.31 (m, 2H), 5.02 (d, J = 2.7 Hz, 1H), 4.30 (brs, 1H), 3.99-3.34 (m, 1H), 1.95-1.79 (m, 2H), 1.74-1.51 (m, 3H), 1.40-1.26 (m, 2H), 1.23-1.05 (m, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 169.1, 152.2, 142.9, 110.6, 108.4, 67.7, 48.6, 32.9, 32.8, 25.5, 24.9, 24.8. IR (thin film): 3288, 2929, 1853, 1647, 1529, 1450, 1252, 1223, 1150, 1059, 1012, 809, 739 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{12}H_{17}NO_3$ 223.1208; Found 223.1208.

General procedure for the Pd-catalyzed *O*-allylation of α-hydroxyphosphonates. To a solution of α-hydroxyphosphonate (1.0 mmol) in toluene (0.5 M solution) was added $Pd_2(dba)_3$ (0.025 mmol), allyl methyl carbonate (1.0 mmol), triphenylphosphine (0.1 mmol) and Cs_2CO_3 (0.25 mmol). The resulting mixture was stirred at the indicated temperature using a heating mantle for the indicated amount of time. The reaction mixture was then filtered over a pad of Celite and concentrated under reduced pressure.

Diethyl[(allyloxy)(thiophen-2-yl)methyl]phosphonate (5j). Yellow oil, 210 mg, 72% isolated yield. R_f = 0.55 (PE/EtOAc = 1:3). ^1H NMR (400 MHz, $CDCl_3$) δ 7.33 (dt, J = 5.1, 1.4 Hz, 1H), 7.18-7.10 (m, 1H), 7.01 (ddd, J = 5.0, 3.5, 0.6 Hz, 1H), 5.87 (dddd, J = 17.1, 10.4, 6.6, 5.1 Hz, 1H), 5.25 (dddd, J = 10.4, 3.9, 3.0, 1.4 Hz, 2H), 4.95 (d, J = 15.7 Hz, 1H), 4.22-3.93 (m, 6H), 1.32-1.22 (m, 6H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 137.6 (d, J = 2.0 Hz), 133.7, 127.8 (d, J = 8.1 Hz), 126.9 (d, J = 2.5 Hz), 126.7 (d, J = 3.4 Hz), 118.7, 72.9 (d, J = 176.9 Hz), 71.2 (d, J = 12.9 Hz), 63.5 (d, J = 7.0 Hz), 63.4 (d, J = 6.8 Hz), 16.6 (d, J = 5.7 Hz), 16.5 (d, J = 5.8 Hz). IR (thin film): 2989, 1717, 1262, 1028 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{12}H_{19}O_4PSNa$ 313.0639; Found 313.0685.

Diethyl[(allyloxy)(furan-3-yl)methyl]phosphonate (5k). Yellow oil, 242 mg, 89% isolated yield. R_f = 0.36 (PE/EtOAc = 1:3). ^1H NMR (400 MHz, $CDCl_3$) δ 7.51-7.47 (m, 1H), 7.41 (t, J = 1.7 Hz, 1H), 6.56-6.51 (m, 1H), 5.86 (dddd, J = 16.8, 10.4, 6.4, 5.2 Hz, 1H), 5.24 (ddq, J = 18.8, 10.4, 1.4 Hz, 2H), 4.67 (d, J = 14.8 Hz, 1H), 4.19-4.03 (m, 5H), 4.00-3.93 (m, 1H), 1.36-1.18 (m, 6H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 143.5, 141.8 (d, J = 11.2 Hz), 134.0, 119.7 (d, J = 1.4 Hz), 118.4, 110.4 (d, J = 3.6 Hz), 71.0 (d, J = 12.3 Hz), 69.6 (d, J = 175.5 Hz), 63.3 (d, J = 6.9 Hz), 63.1 (d, J = 6.7 Hz), 17.8-15.1 (m). IR (thin film): 2980, 1727, 1242, 1048 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{12}H_{19}O_5PNa$ 297.0867; Found 297.0855.

Diethyl[(allyloxy)(thiophen-3-yl)methyl]phosphonate (5l). Yellow oil, 210 mg, 71% isolated yield. R_f = 0.55 (PE/EtOAc = 1:3). ^1H NMR (400 MHz, $CDCl_3$) δ 7.33 (dddd, J = 12.0, 8.0, 3.1, 1.8 Hz, 2H), 7.19 (dt, J = 4.9, 1.1 Hz, 1H), 5.87 (dddd, J = 16.9, 10.4, 6.4, 5.1 Hz, 1H), 5.23 (ddq, J = 17.7, 10.4, 1.4 Hz, 2H), 4.82 (d, J = 15.1 Hz, 1H), 4.18-3.91 (m, 6H), 1.29-1.20 (m, 6H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 135.9 (d, J = 1.4 Hz), 134.0, 127.5 (d, J = 3.7 Hz), 126.1 (d, J = 1.3 Hz), 124.3 (d, J = 9.4 Hz), 118.3, 73.4 (d, J = 172.5 Hz), 71.3 (d, J = 12.9 Hz), 63.3 (d, J = 6.9 Hz), 63.1 (d, J = 6.8 Hz), 16.6 (d, J = 5.7 Hz), 16.5 (d, J = 5.8 Hz). IR (thin film): 2985, 1372, 1257, 1048 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{12}H_{19}O_4PSNa$ 313.0639; Found 313.0685.

Diethyl[(allyloxy)(benzo[b]thiophen-2-yl)methyl]-phosphonate (5m). Yellow oil, 334 mg, 98% isolated yield. R_f = 0.47 (PE/EtOAc = 1:5). ^1H NMR (400 MHz, $CDCl_3$) δ 7.85-7.80 (m, 1H), 7.77-7.72 (m, 1H), 7.39-7.30 (m, 3H),

5.91 (dddd, J = 17.1, 10.4, 6.6, 5.1 Hz, 1H), 5.34-5.22 (m, 2H), 5.04 (dd, J = 16.2, 0.7 Hz, 1H), 4.29-4.00 (m, 6H), 1.33-1.25 (m, 6H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 140.4, 139.5 (d, J = 2.4 Hz), 139.0 (d, J = 2.6 Hz), 133.6, 124.5 (d, J = 18.5 Hz), 124.3 (d, J = 8.9 Hz), 123.8, 122.5, 119.0, 73.6 (d, J = 175.1 Hz), 71.6 (d, J = 12.9 Hz), 63.7 (d, J = 7.0 Hz), 63.5 (d, J = 6.8 Hz), 16.7-16.4 (m). IR (thin film): 2985, 1728, 1261, 1048 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{16}H_{21}O_4PSNa$ 363.0795; Found 363.0802.

Diethyl[(allyloxy)(benzo[b]thiophen-3-yl)methyl] phosphonate (5n). Yellow oil, 334 mg, 98% isolated yield. R_f = 0.45 (PE/EtOAc = 1:5). ^1H NMR (400 MHz, $CDCl_3$) δ 8.01-7.97 (m, 1H), 7.88-7.83 (m, 1H), 7.61 (d, J = 3.6 Hz, 1H), 7.37 (pd, J = 7.1, 1.4 Hz, 2H), 5.88 (dddd, J = 17.0, 10.4, 6.4, 5.1 Hz, 1H), 5.31-5.12 (m, 3H), 4.21-3.85 (m, 6H), 1.28-1.21 (m, 3H), 1.18-1.10 (m, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 140.6, 137.9 (d, J = 4.3 Hz), 133.9, 130.1, 126.6 (d, J = 8.5 Hz), 124.7, 124.3, 123.2, 122.8, 118.5, 72.7 (d, J = 174.6 Hz), 71.3 (d, J = 13.5 Hz), 63.3 (d, J = 6.8 Hz), 63.1 (d, J = 6.8 Hz), 16.6 (d, J = 13.9, 5.8 Hz), 16.5 (d, J = 5.8 Hz). IR (thin film): 2985, 2868, 1430, 1257 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{16}H_{21}O_4PSNa$ 363.0795; Found 363.0802.

(*E*)-Diethyl (1-(allyloxy)-3-phenylallyl)phosphonate (5p). Yellow oil, 225 mg, 73% isolated yield. R_f = 0.35 (CH_2Cl_2/EtOAc = 9:1). ^1H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, J = 7.4 Hz, 2H), 7.33 (t, J = 7.4 Hz, 2H), 7.29-7.22 (m, 1H), 6.71 (dd, J = 16.0, 4.1 Hz, 1H), 6.23(ddd, J = 16.0, 7.3, 5.1 Hz, 1H) 5.95-5.85 (m, 1H), 5.27 (dddd, J = 10.4, 3.9, 2.9, 1.4 Hz, 2H), 4.36 (ddd, J = 16.2, 7.4,1.2 Hz, 1H), 4.26-4.14 (m, 5H), 4.07 (ddt, J = 12.9, 6.3, 1.1 Hz, 1H), 1.32 (t, J = 7.1 Hz, 6H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 136.2 (d, J = 2.7 Hz), 134.6 (d, J = 13.3 Hz), 134.0, 128.7, 128.2, 126.8(d, J = 1.6 Hz), 122.6 (d, J = 4.3 Hz), 118.3, 76.0 (d, J = 169.2 Hz), 71.25 (d, J = 12.0 Hz), 63.3 (d, J = 7.0 Hz), 63.0 (d, J = 6.9 Hz), 16.7 (d, J = 3.9 Hz), 16.6 (d, J = 3.9 Hz). IR (thin film): 3027, 2980, 2907, 1645, 1241, 1097, 1017, 963 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{16}H_{23}O_4P$ 310.1334; Found 310.1345.

(*E*)-Diethyl[1-(allyloxy)-3-(2-methoxyphenyl)allyl] phosphonate (5r). Yellow oil, 246 mg, 72% isolated yield. R_f = 0.4 (CH_2Cl_2/EtOAc = 8:2). ^1H NMR (400 MHz, $CDCl_3$) δ 7.45 (d, J = 7.6 Hz, 1H), 7.24 (m, 1H), 7.02 (dd, J = 16.1, 4.4 Hz, 1H), 6.92 (t, J = 7.6 Hz), 6.86 (d, J = 8.3 Hz, 1H), 6.23 (m, 1H), 5.91 (m, 1H), 5.33-5.20 (m, 2H), 4.36 (dd, J = 15.6, 7.8 Hz, 2H), 4.25-4.03 (m, 6H), 3.83 (s, 3H), 1.32 (t, J = 7.0 Hz, 3H), 1.31 (t, J = 7.1 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 157.0 (d, J = 1.2 Hz), 134.1, 130.1 (d, J = 13.8 Hz), 129.3, 127.3 (d, J = 1.1 Hz), 125.2 (d, J = 2.2 Hz), 123.0 (d, J = 4.2 Hz), 120.7, 118.2, 111.0, 76.6 (d, J = 170.1 Hz), 71.0 (d, J = 12.7 Hz), 63.2 (d, J = 6.9 Hz), 63.0 (d, J = 6.9 Hz), 55.5, 16.6 (d, J = 4.9 Hz), 16.5 (d, J = 5.0 Hz). IR (thin film): 3469, 2979, 2838, 1644, 1292, 1077, 963 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{25}O_5P$ 340.1440; Found 340.1445.

Diethyl (*E*)-{3-(4-methoxyphenyl)-1-[(2-methylallyl)oxy] allyl}phosphonate (5s). Yellow oil (208 mg, 88% isolated yield. R_f = 0.4 (CH_2Cl_2/EtOAc = 4:1). ^1H NMR (400 MHz, $CDCl_3$) δ 7.39-7.31 (m, 2H), 6.90-6.83 (m, 2H), 6.64 (ddd, J = 15.9, 4.5, 1.2 Hz, 1H), 6.07 (ddd, J = 15.9, 7.7, 5.3 Hz, 1H), 4.99 (s, 1H), 4.94 (s, 1H), 4.30 (ddd, J = 15.5, 7.7, 1.2 Hz, 1H), 4.24-4.12 (m, 4H), 4.11 (d, J = 12.7 Hz, 1H), 3.97 (d, J = 12.7 Hz, 1H), 3.81 (s, 3H), 1.76 (s, 3H), 1.31 (td, J = 7.1, 3.5 Hz, 6H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 159.8, 141.5, 134.5 (d, J = 13.5 Hz), 129.1 (d, J = 2.6 Hz), 128.1 (d, J = 1.8 Hz, 2C), 120.2 (d, J = 4.4 Hz), 114.2 (2C), 113.6, 75.9 (d, J = 170.8 Hz), 73.8 (d, J = 12.1 Hz), 63.2 (d, J = 7.0 Hz), 62.9 (d, J = 6.9 Hz), 55.5, 19.7, 16.7 (t, J = 5.5 Hz, 2C). IR (thin film): 3469, 2979, 2838, 1644, 1292, 1077, 963 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{18}H_{27}O_5P$ 354.1596; Found 354.1601.

Diethyl [1-(allyloxy)-1-phenylethyl]phosphonate (5v). Colorless oil, 15 mg, 27% isolated yield. R_f = 0.63 (CH_2Cl_2/EtOAc = 7:3). ^1H NMR (400 MHz, $CDCl_3$) δ 7.55-7.48 (m, 2H), 7.36 (t, J = 7.4 Hz, 2H), 7.30 (dd, J = 7.4, 1.7 Hz, 1H), 5.94 (ddt, J = 17.0, 10.4, 5.2 Hz, 1H), 5.31 (dq, J = 17.0, 1.7 Hz, 1H), 5.14 (ddd, J = 10.4, 3.0, 1.4 Hz, 1H), 4.16-3.92 (m, 5H), 3.80 (dd, J = 12.5, 4.8 Hz, 1H), 1.88 (d, J = 15.9 Hz, 3H), 1.23 (t, J = 6.1 Hz, 3H), 1.20 (t, J = 6.1 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 138.7, 135.0, 128.2 (d, J = 2.4 Hz), 127.9 (d, J = 3.2 Hz), 127.8 (d, J = 4.5 Hz), 116.2, 79.5 (d, J = 169.9 Hz), 64.1 (d, J = 12.7 Hz), 63.4 (d, J = 7.1 Hz), 63.3 (d, J = 6.9 Hz), 19.8, 16.5 (d, J = 5.1 Hz), 16.5 (d, J = 5.2 Hz). IR (thin film): 3403, 3065, 2993, 1446, 1249, 1057, 1029, 839 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{15}H_{23}O_4P$ 298.1334; Found 298.1336.

Diethyl [(allyloxy)(quinolin-3-yl)methyl]phosphonate (5x). Yellow oil, 212 mg, 63% isolated yield. R_f = 0.2 (EtOAc = 100%). ^1H NMR (400 MHz, $CDCl_3$) δ 8.90 (s, 1H), 8.24 (t, J = 2.4 Hz, 1H), 8.07 (d, J = 8.5 Hz, 1H), 7.81 (d, J = 8.1 Hz, 1H), 7.69 (t, J = 7.5 Hz, 1H), 7.52 (t, J = 7.0 Hz, 1H), 5.98-5.72 (m, 1H), 5.27-5.19 (m, 2H), 4.89 (d, J = 16.1 Hz, 1H), 4.31-3.70 (m, 6H), 1.23 (t, J = 7.1 Hz, 3H), 1.21 (t, J = 7.1 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 150.2 (d, J = 5.0 Hz), 148.1 (d, J = 2.1 Hz), 135.4 (d, J = 6.5 Hz), 133.4, 129.9, 129.3, 128.2 (d, J = 1.6 Hz), 128.1, 127.7 (d, J = 2.5 Hz), 127.0, 118.9, 75.16 (d, J = 170.5 Hz), 71.7 (d, J = 13.0 Hz), 63.4 (d, J = 7.1 Hz), 63.2 (d, J = 7.0 Hz), 16.5 (d, J = 5.3 Hz), 16.4 (d, J = 5.3 Hz). IR (thin film): 3052, 2982, 2932, 1496, 1253, 1046, 1020, 963, 788, 731, 700 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{22}NO_4P$ 335.1286; Found 335.1281.

General procedure for the Pd-catalyzed *O*-allylation of α-hydroxyamides. To a solution of α-hydroxyamide (2.0 mmol) in toluene (0.5 M solution) were added $Pd_2(dba)_3$ (0.05 mmol), allyl methyl carbonate (2.0 mmol) and triphenylphosphine (0.2 mmol) and the resulting mixture was stirred at 50 °C using a heating mantle for 30 min. The reaction mixture was then filtered over a pad of Celite and concentrated under reduced pressure. After evaporation of the solvent under reduced pressure, the crude residue was purified by flash column chromatography over silica gel.

(*E*)-2-(Allyloxy)-*N*-(*tert*-butyl)-4-(4-methoxyphenyl)but-3-enamide (6a). Yellow oil, 492 mg, 81% isolated yield. R_f = 0.33 (PE/Et_2O = 6:4). ^1H NMR (400 MHz, $CDCl_3$) δ 7.33 (d, J = 8.8 Hz, 2H), 6.84 (d, J = 8.8 Hz, 2H), 6.64 (dd, J = 15.9, 0.7 Hz, 1H), 6.50 (brs, 1H), 6.02 (dd, J = 15.9, 6.6 Hz, 1H), 5.99-5.87 (m, 1H), 5.42-5.06 (m, 2H), 4.29 (dd, J = 6.6, 1.3 Hz, 1H), 4.23-3.94 (m, 2H), 3.80 (s, 3H), 1.37 (s, 9H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 169.9, 159.6, 134.0, 133.1, 129.1, 128.1, 122.9, 117.8, 114.0, 80.9, 70.4, 55.4, 51.0, 28.9. IR (thin film): 3406, 2966, 2934, 2868, 1675, 1606, 1510, 1454, 1364, 1249, 1174, 1032, 967, 734 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{18}H_{25}NO_3$ 303.1834; Found 303.1843.

(*E*)-2-(Allyloxy)-*N*-cyclohexyl-4-(4-methoxyphenyl)but-3-enamide (6b). Yellow solid, 525 mg, 80% isolated yield. R_f = 0.33 (PE/Et_2O = 4:6). mp = 83-85 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.30 (d, J = 8.7 Hz, 2H), 6.81 (d, J = 8.7 Hz, 2H), 6.63 (d, J = 15.6 Hz, 1H), 6.55 (br, 1H), 6.02

(dd, J = 15.6, 6.6 Hz, 1H), 5.97-5.83 (m, 1H), 5.34-5.17 (m, 2H), 4.37 (dd, J = 6.6, 1.3 Hz, 1H), 4.20-3.91 (m, 2H), 3.85-3.63 (m, 1H), 3.76 (s, 3H), 1.97-1.79 (m, 2H), 1.77-1.51 (m, 3H), 1.46-1.27 (m, 2H), 1.23-1.07 (m, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 169.7, 159.4, 133.8, 132.9, 128.9, 127.9, 122.7, 117.8, 113.9, 80.3, 70.3, 55.2, 47.7, 33.1, 33.0, 25.5, 24.8. IR (thin film): 3409, 3312, 2930, 2854, 1667, 1606, 1509, 1450, 1249, 1032, 823, 733 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{20}H_{27}NO_3$ 329.1991; Found 329.1997.

(*E*)-2-(Allyloxy)-*N*-(*tert*-butyl)-4-phenylbut-3-enamide (6c). Yellow oil, 437 mg, 77% isolated yield. R_f = 0.35 (PE/Et_2O = 7:3). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43-7.26 (m, 5H), 6.72 (dd, J = 16.0, 1.1 Hz, 1H), 6.52 (brs, 1H), 6.21 (dd, J = 16.0, 6.4 Hz, 1H), 6.08-5.79 (m, 1H), 5.45-5.14 (m, 2H), 4.34 (dd, J = 6.4, 1.4 Hz, 1H), 4.25-3.93 (m, 2H), 1.39 (s, 9H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 169.7, 136.3, 133.9, 133.3, 128.6, 128.0, 126.8, 125.3, 117.9, 80.8, 70.6, 51.1, 28.9. IR (thin film): 3407, 3026, 2967, 2868, 1677, 1514, 1451, 1364, 1225, 1071, 1044, 966, 734 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{23}NO_2$ 273.1729; Found 273.1716.

(*E*)-2-(Allyloxy)-*N*-cyclohexyl-4-(furan-2-yl)but-3-enamide (6d). Yellow oil, 240 mg, 83% isolated yield. R_f = 0.33 (PE/Et_2O = 1:1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (d, J = 1.6 Hz, 1H), 6.53 (dd, J = 15.9, 1.3 Hz, 1H), 6.50 (brs, 1H), 6.36 (dd, J = 3.3, 1.6 Hz, 1H), 6.27 (d, J = 3.3 Hz, 1H), 6.13 (dd, J = 15.9, 6.3 Hz, 1H), 5.98-5.83 (m, 1H), 5.37-5.17 (m, 2H), 4.38 (dd, J = 6.3, 1.3 Hz, 1H), 4.20-3.96 (m, 2H), 3.84-3.69 (m, 1H), 1.97-1.79 (m, 2H), 1.75-1.53 (m, 3H), 1.46-1.27 (m, 2H), 1.26-1.05 (m, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 169.4, 152.1, 142.4, 133.8, 123.9, 121.3, 118.1, 111.5, 108.9, 80.0, 70.6, 47.8, 33.3, 33.1, 25.6, 24.9. IR (thin film): 3405, 3312, 2930, 2854, 1656, 1517, 1450, 1264, 1151, 1013, 927, 731, 701 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{23}NO_3$ 289.1678; Found 289.1685.

2-(Allyloxy)-*N*-cyclohexyl-2-(furan-2-yl)acetamide (6e). Yellow oil, 442 mg, 84% isolated yield. R_f = 0.40 (PE/Et_2O = 3:7). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (dd, J = 1.9, 0.8 Hz, 1H), 6.74 (br, 1H), 6.39 (d, J = 3.2 Hz, 1H), 6.34 (dd, J = 3.2, 1.9 Hz, 1H), 6.00-5.71 (m, 1H), 5.38-5.10 (m, 2H), 4.83 (s, 1H), 4.14-3.91 (m, 2H), 3.90-3.68 (m, 1H), 2.02-1.84 (m, 2H), 1.82-1.52 (m, 3H), 1.49-1.30 (m, 2H), 1.29-1.09 (m, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 167.3, 150.1, 143.3, 133.5, 118.5, 110.5, 110.5, 74.7, 70.3, 48.0, 33.1, 25.6, 24.9. IR (thin film): 3318, 2932, 2855, 1730, 1658, 1533, 1451, 1349, 1260, 1151, 1094, 892, 749 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{15}H_{21}NO_3$ 263.1521; Found 263.1514.

General procedure for the sequential DBU-mediated isomerization/Claisen rearrangement of the *O*-allylated Passerini adducts. A mixture of the *O*-allylated Passerini adduct (1 equiv, 0.5 mmol), DBU (0.5 equiv, 0.25 mmol, 0.04 mL), and toluene (2 mL, 0.25 M) was stirred at 120 °C for 30 min under microwave irradiation. After evaporation of the solvent under reduced pressure, the crude residue was purified by flash column chromatography over silica gel.

***N*-(*tert*-Butyl)-3-(4-methoxybenzyl)-2-oxohex-5-enamide (7a).** Yellow oil, 99 mg, 65% isolated yield. R_f = 0.35 (PE/Et_2O = 9:1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08 (d, J = 8.7 Hz, 2H), 6.86 (d, J = 8.7 Hz, 2H), 6.70 (brs, 1H), 5.81-5.51 (m, 1H), 5.12-4.85 (m, 2H), 4.08-3.88 (m, 1H), 3.76 (s, 3H), 2.89 (dd, J = 13.8, 7.4 Hz, 1H), 2.68 (dd, J = 13.8, 7.1 Hz, 1H), 2.50-2.08 (m, 2H), 1.33 (s, 9H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 202.4, 159.2, 158.2, 135.1, 130.9, 130.2, 117.3, 113.9, 55.3, 51.3, 45.4, 35.8, 35.0, 28.3. IR (thin film): 3394, 2968, 2933, 2836, 1714, 1681, 1641, 1612, 1453, 1365, 1245, 1225, 1177, 1082, 1035, 991, 916 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{18}H_{25}NO_3$ 303.1834; Found 303.1840.

***N*-Cyclohexyl-3-(4-methoxybenzyl)-2-oxohex-5-enamide (7b).** Yellow oil, 131 mg, 79% isolated yield. R_f = 0.33 (PE/Et_2O = 8:2). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.07 (d, J = 8.7 Hz, 2H), 6.79 (d, J = 8.7 Hz, 2H), 6.72 (br, 1H), 5.82-5.56 (m, 1H), 5.08-4.83 (m, 2H), 4.06-3.89 (m, 1H), 3.76 (s, 3H), 3.73-3.61 (m, 1H), 2.92 (dd, J = 13.9, 7.3 Hz, 1H), 2.68 (dd, J = 13.9, 7.1 Hz, 1H), 2.44-2.364(m, 1H), 2.31-2.20 (m, 1H), 1.93-1.78 (m, 2H), 1.74-1.56 (m, 3H), 1.42-1.07 (m, 5H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 201.7, 159.0, 158.2, 135.1, 130.9, 130.2, 117.3, 114.0, 55.3, 48.5, 45.9, 35.7, 34.9, 32.7, 25.5, 24.8 IR (thin film): 3370, 2930, 2854, 1714, 1668, 1611, 1510, 1449, 1244, 1177, 1106, 1034, 915 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{20}H_{27}NO_3$ 329.1991; Found 329.1990.

3-Benzyl-*N*-(*tert*-butyl)-2-oxohex-5-enamide (7c). Yellow oil, 121 mg, 88% isolated yield. R_f = 0.4 (PE/Et_2O = 9:1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-6.93 (m, 5H), 6.63 (brs, 1H), 5.74-5.43 (m, 1H), 5.06-4.73 (m, 2H), 4.14-3.75 (m, 1H), 2.88 (dd, J = 13.8, 7.4 Hz, 1H), 2.65 (dd, J = 13.8, 7.1 Hz, 1H), 2.44-1.95 (m, 2H), 1.26 (s, 9H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 202.2, 159.1, 139.0, 135.0, 129.2, 128.5, 126.4, 117.3, 51.3, 45.1, 36.6, 35.0, 28.3. IR (thin film): 3394, 3064, 2970, 2930, 1714, 1682, 1641, 1515, 1454, 1365, 1225, 1072, 915, 741 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{23}NO_2$ 273.1729; Found 273.1733.

***N*-Cyclohexyl-3-(furan-2-ylmethyl)-2-oxohex-5-enamide (7d).** Yellow solid, 110 mg, 76% isolated yield. R_f = 0.31 (PE/Et_2O = 9:1). mp = 63-65 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (dd, J = 1.9, 0.8 Hz, 1H), 6.75 (br, 1H), 6.23 (dd, J = 3.2, 1.9 Hz, 1H), 5.98 (dd, J = 3.2, 0.7 Hz, 1H) 5.84-5.52 (m, 1H), 5.17-4.79 (m, 2H), 4.07-3.94 (m, 1H), 3.79-3.64 (m, 1H), 2.99 (dd, J = 15.2, 7.8 Hz, 1H), 2.89 (dd, J = 15.2, 6.1 Hz, 1H), 2.47-2.36 (m, 1H), 2.34-2.24 (m, 1H), 1.96-1.82 (m, 2H), 1.77-1.66 (m, 3H), 1.67-1.54 (m, 2H), 1.44-1.30 (m, 2H), 1.26-1.09 (m, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 201.1, 158.9, 152.9, 141.5, 134.6, 117.8, 110.3, 106.7, 48.5, 43.4, 35.1, 32.8, 28.6, 25.5, 24.8. IR (thin film): 3371, 3318, 2930, 1717, 1667, 1517, 1450, 1372, 1147, 1108, 1011, 917, 728 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{23}NO_3$ 289.1678; Found 289.1668.

General procedure for the sequential DBU-mediated isomerization/Claisen rearrangement/amine addition on the *O*-allylated Pudovik adducts. A solution of the *O*-allylated Pudovik adduct (0.5 mmol, 1 equiv.), DBU (0.04 mL, 0.25 mmol, 0.5 equiv.), and the amine (0.75 mmol, 1.5 equiv.) in toluene (1 mL, 0.5 M) was stirred at 130 °C for 30 min under microwave irradiation. After evaporation of the solvent under reduced pressure, the crude residue was purified by flash column chromatography over silica gel.

2-Benzyl-*N*-(2-methylallyl)pent-4-enamide (9a). White solid, 73 mg, 60% isolated yield. R_f = 0.31 (PE/Et_2O = 7:3). mp = 45-47 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33-7.07 (m, 5H), 5.83-5.70 (m, 1H), 5.36 (brs, 1H), 5.10 (ddd, J = 17.0, 3.2, 1.4 Hz, 1H), 5.13-5.02 (m, 2H), 4.70-4.68 (m, 1H), 4.55-4.53 (m, 1H), 3.68 (d, J = 5.9 Hz, 2H), 2.93 (dd, J = 13.5, 9.3 Hz, 1H), 2.76 (dd, J = 13.5, 5.3 Hz, 1H), 2.51-2.42 (m, 1H), 2.37 (ddd, J = 18.0, 9.0, 5.2 Hz, 1H) 2.30-2.21 (m, 1H), 1.56 (s, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 174.1, 141.9, 139.8, 135.8, 129.1, 128.5, 126.4, 117.2, 111.0, 50.4, 44.9, 38.8, 37.0, 20.3. IR (thin film): 3444, 3045, 2919, 1675, 1604, 1516, 1454, 1202 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{16}H_{21}NO$ 243.1623; Found 243.1615.

2-(2-Methoxybenzyl)-*N*-(2-methylallyl)pent-4-enamide (9b). White solid, 90 mg, 66% isolated yield. R_f = 0.37 (PE/Et_2O = 7:3). mp = 69-71 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.18 (td, J = 7.9, 1.7 Hz, 1H), 7.10 (dd, J = 7.4, 1.5 Hz, 1H), 6.87-6.82 (m, 2H), 5.89-5.79 (m, 1H), 5.42 (brs, 1H), 5.16-5.04 (m, 2H), 4.76-4.74 (m, 1H), 4.64-4.62 (m, 1H), 3.82 (s, 3H), 3.73 (d, J = 6.0 Hz, 2H), 2.87-2.80 (m, 2H), 2.56-2.39 (m, 2H), 2.29-2.15 (m, 1H), 1.57 (s, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 174.6, 157.4, 142.2, 136.2, 131.2, 128.0, 127.8, 120.6, 116.7, 110.9, 110.3, 55.4, 47.7, 44.8, 36.9, 33.7, 20.3. IR (thin film): 3044, 3045, 2986, 2839, 1674, 1602, 1515, 1466, 1241, 1031 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{23}NO_2$ 273.1729; Found 273.1727.

2-(4-Methoxybenzyl)-*N*-(2-methylallyl)pent-4-enamide (9c). White solid, 88 mg, 64% isolated yield. R_f = 0.25 (PE/Et_2O = 6:4). mp = 63-65 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.06 (d, J = 8.6 Hz, 2H), 6.78 (d, J = 8.6 Hz, 2H), 5.76 (ddt, J = 17.1, 10.1, 6.9 Hz, 1H), 5.55 (brs, 1H), 5.10-5.00 (m, 2H), 4.69 (s, 1H), 4.56 (s, 1H), 3.75 (s, 3H), 3.67 (d, J = 5.9 Hz, 1H), 2.85 (dd, J = 13.6, 9.1 Hz, 1H), 2.68 (dd, J = 13.6, 5.3 Hz, 1H), 2.49-2.29 (m, 2H), 2.28-2.15 (m, 1H), 1.56 (s, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 174.2, 158.1, 141.9, 135.8, 131.8, 130.0, 117.0, 113.9, 110.9, 55.3, 50.3, 44.8, 37.8, 36.9, 20.3. IR (thin film): 3444, 3055, 2986, 2921, 2852, 1671, 1613, 1515, 1452, 1232, 1035 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{23}NO_2$ 273.1729; Found 273.1730.

***N*-Butyl-2-(4-methoxybenzyl)pent-4-enamide (9d).** Yellow oil, 106 mg, 77% isolated yield. R_f = 0.35 (PE/Et_2O = 1:1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.07 (d, J = 8.6 Hz, 2H), 6.80 (d, J = 8.6 Hz, 2H), 5.82-5.69 (m, 1H), 5.13 (brs, 1H), 5.11-5.00 (m, 2H), 3.77 (s, 3H), 3.22-3.01 (m, 2H), 2.84 (dd, J = 13.6, 9.2 Hz, 1H), 2.69 (dd, J = 13.6, 5.0 Hz, 1H), 2.50-2.36 (m, 1H), 2.30-2.13 (m, 2H), 1.34-1.22 (m, 2H), 1.21-1.07 (m, 2H), 0.83 (t, J = 7.3 Hz, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 174.2, 158.2, 136.0, 132.0, 130.0, 117.0, 113.9, 55.4, 50.5, 39.1, 38.0, 36.9, 31.7, 20.0, 13.8. IR (thin film): 3292, 2956, 2931, 1639, 1549, 1511, 1242, 1176, 1036, 912 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{25}NO_2$ 275.1885; Found 275.1877.

2-(4-Methoxybenzyl)-1-(piperidin-1-yl)pent-4-en-1-one (9e). Yellow oil, 55 mg, 38% isolated yield. R_f = 0.35 (PE/Et_2O = 1:1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.01 (d, J = 8.6 Hz, 2H), 6.72 (d, J = 8.6 Hz, 2H), 5.78-5.51 (m, 1H), 5.06-4.79 (m, 2H), 3.70 (s, 3H), 3.56-3.28 (m, 2H), 3.19-2.98 (m, 2H), 2.94-2.85 (m, 1H), 2.80 (dd, J = 13.0, 9.3 Hz, 1H), 2.61 (dd, J = 13.0, 5.1 Hz, 1H), 2.44-2.35 (m, 1H), 2.23-2.07 (m, 1H), 1.48-1.18 (m, 5H), 0.96-0.83 (m, 1H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 172.9, 158.1, 136.1, 132.1, 130.1, 116.6, 113.7, 55.3, 46.7, 43.2, 42.9, 38.2, 37.2, 26.3, 25.8, 24.6. IR (thin film): 2936, 2856, 1624, 1511, 1442, 1243, 1035, 732 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{18}H_{25}NO_2$ 287.1885; Found 287.1818.

General procedure for the sequential DBU-mediated isomerization/Claisen rearrangement/indole addition on the *O*-allylated Pudovik adducts. A solution of the *O*-allylated Pudovik adduct (0.5 mmol), DBU (0.04 mL, 0.25 mmol, 0.5 equiv.) and the indole (0.5 mmol, 1 equiv.) in toluene (1 mL, 0.5 M) was stirred at 140 °C for 30 min under microwave irradiation. After evaporation of the solvent under reduced pressure, the crude residue was purified by flash column chromatography over silica gel.

1-(1*H*-Indol-1-yl)-2-(4-methoxybenzyl)pent-4-en-1-one (9f). Colorless oil, 101 mg, 63% isolated yield. R_f = 0.34 (PE/Et_2O = 9:1). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.53 (d, J = 8.3 Hz, 1H), 7.53 (dd, J = 7.8, 0.6 Hz, 1H), 7.38-7.33 (m, 1H), 7.31 (d, J = 3.8 Hz, 1H), 7.29-7.24 (m, 1H), 7.10 (d, J = 8.6Hz, 2H), 6.76 (d, J = 8.6Hz, 2H), 6.55 (dd, J = 3.8, 0.6 Hz, 1H), 5.84-5.75 (m, 1H), 5.13-5.01 (m, 2H), 3.74 (s, 3H), 3.45-3.40 (m, 1H), 3.14 (dd, J = 13.8, 8.1 Hz, 1H), 2.89 (dd, J = 13.8, 6.1 Hz, 1H), 2.68-2.61 (m, 1H), 2.46-2.40 (m, 1H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 173.9, 158.4, 135.8, 134.8, 130.9, 130.6, 130.0, 125.2, 124.6, 123.8, 120.8, 117.9, 117.1, 114.1, 109.2, 55.34, 47.3, 37.6, 36.8. IR (thin film): 3074, 2997, 2835, 1697, 1583, 1300, 1203, 1033, 920, 818 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{21}H_{21}NO_2$ 319.1572; Found 319.1584.

Methyl 1-[2-(4-methoxybenzyl)pent-4-enoyl]-1*H*-indole-3-carboxylate (9g). White solid, 77 mg, 41% isolated yield. R_f = 0.29 (PE/Et_2O = 8:2). mp = 85 °C. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.50 (d, J = 7.4 Hz, 1H), 8.12 (d, J = 6.8 Hz, 1H), 7.95 (s, 1H), 7.46-7.32 (m, 2H), 7.07 (d, J = 8.6 Hz, 2H), 6.74 (d, J = 8.6 Hz, 2H), 5.83-5.78 (m, 1H), 5.21-4.90 (m, 2H), 3.93 (s, 3H), 3.72 (s, 3H), 3.48-3.41 (m, 1H), 3.10 (dd, J = 13.8, 8.5 Hz, 1H), 2.94 (dd, J = 13.8, 5.8 Hz, 1H), 2.68-2.61 (m, 1H), 2.52-2.38 (m, 1H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 174.2, 164.5, 158.5, 136.1, 134.2, 130.6, 130.4, 129.9, 127.5, 126.0, 125.0, 121.5, 118.4, 116.9, 114.2, 113.7, 55.3, 51.7, 47.5, 37.7, 36.8. IR (thin film): 2949, 2835, 1704, 1640, 1550, 1245, 1185, 1102 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{23}H_{23}NO_4$ 377.1627; Found 377.1630.

1-(1*H*-Indol-1-yl)-2-(2-methoxybenzyl)pent-4-en-1-one (9h). Brown oil, 98 mg, 61% isolated yield. R_f = 0.4 (PE/Et_2O = 9.5:0.5). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.57 (d, J = 8.3 Hz, 1H), 7.61-7.45 (m, 2H), 7.41-7.33 (m, 1H), 7.27 (td, J = 7.5, 1.1 Hz, 1H), 7.20 (td, J = 7.9, 1.7 Hz, 1H), 7.14 (dd, J = 7.5, 1.4 Hz, 1H), 6.86-6.82 (m, 2H), 6.56 (dd, J = 3.8, 0.6 Hz, 1H), 5.83-5.78 (m; 1H), 5.10-4.97 (m, 2H), 3.81 (s, 3H), 3.65-3.60 (m, 1H) 3.21 (dd, J = 13.3, 6.6 Hz, 1H), 2.90 (dd, J = 13.3, 7.5 Hz, 1H), 2.73-2.68 (m, 1H), 2.38-2.31 (m, 1H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 174.3, 157.5, 135.8, 135.4, 131.5, 130.6, 128.3, 126.9, 125.0, 124.9, 123.7, 120.7, 120.6, 117.2, 117.1, 110.4, 108.7, 55.3, 44.4, 36.0, 34.6. IR (thin film): 3074, 2997, 2836, 1700, 1493, 1314, 1205, 1050, 919, 897 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{21}H_{21}NO_2$ 319.1572; Found 319.1573.

General procedure for the sequential DBU-mediated isomerization/Claisen rearrangement/nucleophilic addition. A mixture of the *O*-allylated Pudovik adduct (0.5 mmol), DBU (0.04 mL, 0.25 mmol, 0.5 equiv.) and the corresponding alcohol (1 mL, 0.5 M) or a 2:1 toluene/thiol mixture was stirred at 140 °C for 30 min under microwave irradiation. After evaporation of the solvent under reduced pressure, the crude residue was purified by flash column chromatography over silica gel.

Ethyl 2-(2-methoxybenzyl)pent-4-enoate (9i). Colourless oil, 111 mg, 89% isolated yield. R_f = 0.3 (PE/Et_2O = 9.5:0.5). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 (td, J = 7.9, 1.7 Hz, 1H), 7.10 (dd, J = 7.3, 1.5 Hz, 1H), 6.87-6.82 (m, 2H), 5.80-5.72 (m, 1H), 5.09-5.00 (m, 2H), 4.04 (qd, J = 7.1, 2.0 Hz, 2H), 3.82 (s, 3H), 2.87-2.81 (m, 3H), 2.38 (m, 1H), 2.27 (m, 1H), 1.13 (t, J = 7.1 Hz, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 175.4, 157.7, 135.7, 130.9, 127.8, 127.7, 120.3, 116.8, 110.3, 60.2, 55.3, 45.3, 36.5, 33.0, 14.3. IR (thin film): 2978, 2936, 2361, 1729, 1601, 1289, 1176, 1050, 917, 855 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{15}H_{20}O_3$ 248.1412; Found 248.1414.

2,2,2-Trifluoroethyl-2-(4-methoxybenzyl)pent-4-enoate (9j). Colourless oil, 80 mg, 53% isolated yield. R_f = 0.35 (PE/Et_2O = 9:1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08 (d, J = 8.4 Hz, 2H), 6.83 (d, J = 8.4 Hz, 2H), 5.80-5.70 (m, 1H),

5.11-5.06 (m, 2H), 4.49-4.29 (m, 2H), 3.79 (s, 3H), 2.94-2.76 (m, 3H), 2.44-2.29 (m, 2H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 173.4, 158.4, 134.6, 130.6, 129.9, 123.1(q, J = 277.1 Hz), 114.0, 60.2 (q, J = 36.6 Hz), 55.3, 47.4, 36.8, 35.9. IR (thin film): 2949, 2835, 1704, 1640, 1550, 1245, 1185, 1102 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{15}H_{17}F_3O_3$ 302.1130; Found 302.1142.

***S*-Ethyl 2-(4-methoxybenzyl)pent-4-enethioate (9k).** Yellow oil, 88 mg, 67% isolated yield. R_f = 0.35 (PE/Et_2O = 9.5:0.5). ^1H NMR (400 MHz, $CDCl_3$) δ 7.06 (d, J = 8.6 Hz, 2H), 6.81 (d, J = 8.7 Hz, 2H), 5.74 (ddt, J = 17.1, 10.2, 7.0 Hz, 1H), 5.28-4.71 (m, 2H), 3.78 (s, 3H), 2.99-2.77 (m, 4H), 2.70 (dd, J = 13.0, 6.1 Hz, 1H), 2.48-2.34 (m, 1H), 2.31-2.15 (m, 1H), 1.18 (t, J = 7.4 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 202.4, 158.3, 135.0, 131.0, 130.2, 117.4, 113.9, 56.0, 55.3, 37.5, 36.5, 23.3, 14.9. IR (thin film): 3045, 2933, 2840, 1680, 1613, 1513, 1448, 1299, 1230, 1179, 1035, 925 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{15}H_{20}O_2S$ 264.1184; Found 264.1186.

General procedure for the sequential [Ru-H]-catalyzed isomerization/Claisen rearrangement. A solution of the *O*-allylated Pudovik or Passerini adduct (0.5 mmol), $RuClH(CO)(PPh_3)_3$ (0.025 mmol, 0.05 equiv.) in toluene (1 mL, 0.5M) was heated under microwave irradiation at the indicated temperature for 30 min. After evaporation, the crude residue was purified by flash column chromatography over silica gel.

(*E*)-Diethyl (3-(4-methoxyphenyl)-4-methyl-5-oxopent-1-en-1-yl)phosphonate (10a). It was unfortunately impossible to separate and precisely distinguish the *syn* from the *anti* isomer (dr = 1:1). Yellow oil, 112 mg, 66% 41% isolated yield. R_f = 0.43 (CH_2Cl_2/AcOEt = 6:4). **First diasteroisomer:** ^1H NMR (400 MHz, $CDCl_3$) δ 9.68 (d, J = 2.4 Hz, 1H), 7.09 (d, J = 8.7 Hz, 2H), 6.95-6.79 (m, 3H), 5.81-5.44 (m, 1H), 4.10-3.91 (m, 8H), 3.78 (s, 3H), 3.70-3.59 (m, 1H), 2.95-2.62 (m, 1H), 1.37-1.19 (m, 6H), 0.93 (d, J = 7.1 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 203.3, 158.9, 153.1 (d, J = 5.0 Hz), 131.1, 129.5, 119.6 (d, J = 62.8 Hz), 114.5, 70.0 (d, J = 5.0 Hz), 55.4, 51.0 (d, J = 21.7 Hz), 50.3, 16.5 (d, J = 3.8 Hz), 12.6. **Second diasteroisomer:** ^1H NMR (400 MHz, $CDCl_3$) δ 9.49 (d, J = 2.3 Hz, 1H), 7.05 (d, J = 8.7 Hz, 2H), 6.95-6.79 (m, 3H), 5.81-5.44 (m, 1H), 4.10-3.91 (m, 8H), 3.77 (s, 3H), 3.70-3.59 (m, 1H), 2.95-2.62 (m, 1H), 1.37-1.19 (m, 6H), 1.14 (d, J = 7.0 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 203.2, 158.9, 152.4 (d, J = 5.1 Hz), 130.5, 129.2, 117.7 (d, J = 62.9 Hz), 114.4, 61.9 (d, J = 5.6 Hz), 55.4, 50.2, 50.1 (d, J = 21.7 Hz), 16.4 (d, J = 3.2 Hz), 12.4. IR (thin film): 2980, 2934, 2906, 2837, 1722, 1608, 1511, 1246, 1177, 1018, 962, 833, 722 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{25}O_5P$ 340.1440; Found 340.1439.

(*E*)-*N*-(*tert*-butyl)-4-(4-methoxyphenyl)-5-methyl-6-oxohex-2-enamide (10b). It was unfortunately impossible to separate and precisely distinguish the *syn* from the *anti* isomer (dr = 1:1). Yellow oil, 105 mg, 69% isolated yield. R_f = 0.3 (PE/Et_2O = 3:7). **First diasteroisomer:** ^1H NMR (400 MHz, $CDCl_3$) δ 9.70 (d, J = 2.3 Hz, 1H), 7.10 (d, J = 8.7 Hz, 2H), 6.98-6.88 (m, 1H), 6.85 (d, J = 8.7 Hz, 2H), 5.81-5.54 (m, 1H), 5.32 (brs, 1H), 3.78 (s, 3H), 3.65-3.56 (m, 1H), 2.89-2.67 (m, 1H), 1.34 (s, 9H), 1.14 (d, J = 7.0 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 204.1, 164.6, 158.8, 143.6, 143.0, 132.1, 131.5, 129.4, 129.2, 126.3, 125.8, 114.4, 114.3, 55.4, 51.5, 50.7, 48.9, 28.9, 12.5. **Second diasteroisomer:** ^1H NMR (400 MHz, $CDCl_3$) δ 9.50 (d, J = 2.3 Hz, 1H), 7.07 (d, J = 8.7 Hz, 1H), 6.98-6.88 (m, 1H), 6.84 (d, J = 8.7 Hz, 2H), 5.81-5.54 (m, 1H), 5.32 (brs, 1H), 3.77 (s, 3H), 3.65-3.56 (m, 1H), 2.89-2.67 (m, 1H), 1.33 (s, 9H), 0.91 (d, J = 7.1 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 203.9, 164.6, 158.7, 143.6, 143.0, 132.1, 131.5, 129.4, 129.2, 126.3, 125.8, 114.4, 114.3, 55.4, 51.5, 50.6, 48.4, 28.9, 12.4. IR (thin film): 3316, 2968, 2934, 2838, 1722, 1670, 1634, 1610, 1511, 1422, 1392, 1364, 1264, 1250, 1179, 1034, 981, 731 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{18}H_{25}NO_3$ 303.1834; Found 303.1843.

(*E*)-*N*-Cyclohexyl-4-(4-methoxyphenyl)-5-methyl-6-oxohex-2-enamide (10c). It was unfortunately impossible to separate and precisely distinguish the *syn* from the *anti* isomer (dr = 1:1). Brown solid, 140 mg, 85% isolated yield. R_f = 0.3 (PE/Et_2O = 2:8). mp = 146 °C. **First diasteroisomer:** ^1H NMR (400 MHz, $CDCl_3$) δ 9.69 (d, J = 2.4 Hz, 1H), 7.10 (d, J = 8.7 Hz, 2H), 7.00-6.90 (m, 1H), 6.85 (d, J = 8.7 Hz, 2H), 5.71 (dd, J = 15.1, 1.1 Hz, 1H), 5.45 (br, 1H), 3.83-3.72 (m, 1H), 3.78 (s, 3H), 3.66-3.56 (m, 1H), 2.86-2.77 (m, 1H), 1.94-1.81 (m, 2H), 1.73-1.54 (m, 3H), 1.40-1.27 (m, 2H), 1.13 (d, J = 7.0 Hz, 3H), 1.18-1.00 (m, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 204.0, 164.3, 158.7, 144.0, 143.4, 132.0, 131.4, 129.4, 129.2, 125.5, 125.0, 114.4, 114.3, 55.4, 50.6, 49.0, 48.4, 33.2, 25.6, 24.9, 12.5, 12.4. **Second diasteroisomer:** ^1H NMR (400 MHz, $CDCl_3$) δ 9.50 (d, J = 2.4 Hz, 1H), 7.07 (d, J = 8.7 Hz, 2H), 7.00-6.90 (m, 1H), 6.83 (d, J = 8.7 Hz, 2H), 5.71 (dd, J = 15.1, 1.1 Hz, 1H), 5.45 (br, 1H), 3.83-3.72 (m, 1H), 3.76 (s, 3H), 3.66-3.56 (m, 1H), 2.86-2.77 (m, 1H), 1.94-1.81 (m, 2H), 1.73-1.54 (m, 3H), 1.40-1.27 (m, 2H), 1.18-1.00 (m, 3H), 0.91 (d, J = 7.1 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 203.9, 164.3, 158.7, 144.0, 143.4, 132.0, 131.4, 129.4, 129.2, 125.5, 125.0, 114.4, 114.3, 55.4, 50.6, 49.0, 48.3, 33.2, 25.6, 24.9, 12.5, 12.4. IR (thin film): 3287, 2952, 2854, 1722, 1665, 1625, 1511, 1264, 1249, 1179, 1033, 981, 732 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{20}H_{27}NO_3$ 329.1991; Found 329.2000.

(*E*)-*N*-(*tert*-Butyl)-5-methyl-6-oxo-4-phenylhex-2-enamide (10d). It was unfortunately impossible to separate and precisely distinguish the *syn* from the *anti* isomer (dr = 1:1). Yellow oil, 107 mg, 78% isolated yield. R_f = 0.28 (PE/Et_2O = 4:6). **First diasteroisomer:** ^1H NMR (400 MHz, $CDCl_3$) δ 9.70 (d, J = 2.4 Hz, 1H), 7.43-7.07 (m, 5H), 6.98-6.91 (m, 1H), 5.71 (d, J = 15.1 Hz, 1H), 5.47 (br, 1H), 3.69-3.60 (m, 1H), 2.92-2.76 (m, 1H), 1.33 (s, 9H), 1.13 (d, J = 7.0 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 203.9, 164.6, 143.2, 140.2, 139.5, 129.0, 129.0, 128.4, 128.1, 127.3, 126.6, 126.1, 51.4, 50.6, 49.6, 28.8, 12.5. **Second diasteroisomer:** ^1H NMR (400 MHz, $CDCl_3$) δ 9.50 (d, J = 2.2 Hz, 1H), 7.43-7.07 (m, 5H), 6.98-6.91 (m, 1H), 5.71 (d, J = 15.1 Hz, 1H), 5.47 (br, 1H), 3.69-3.60 (m, 1H), 2.92-2.76 (m, 1H), 1.32 (s, 9H), 0.90 (d, J = 7.1 Hz, 3H). $^{13}C\{1H\}$ NMR (101 MHz, $CDCl_3$) δ 203.7, 164.5, 142.5, 140.2, 139.5, 129.0, 129.0, 128.4, 128.1, 127.3, 126.6, 126.1, 51.4, 50.4, 49.2, 28.8, 12.4. IR (thin film): 3295, 3062, 2968, 2932, 1721, 1666, 1628, 1538, 1453, 1362, 1265, 1222, 981, 910, 734 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{23}NO_2$ 273.1729; Found 273.1737.

General procedure for the sequential [Ru-H]-catalyzed isomerization/Claisen rearrangement of the heteroaromatic *O*-allylated Passerini and Pudovik adducts. To a solution of the *O*-allylated Pudovik or Passerini adduct (0.1 mmol) in $CHCl_3$ (0.1M) was added $RuClH(CO)(PPh_3)_3$ (0.005 mmol, 0.05 equiv.) and the resulting mixture was heated at 180 °C for 10 min under microwave irradiation. The reaction mixture was filtered through Celite, concentrated under reduced pressure and the crude residue was purified by flash column chromatography over silica gel.

Diethyl[(3-(1-oxopropan-2-yl)furan-2-yl)methyl]-phosphonate (11a). Yellow oil, 17 mg, 62% isolated yield. R_f = 0.32 (PE/EtOAc = 1:3). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (d, J = 1.2 Hz, 1H), 7.33 (d, J = 1.8 Hz, 1H), 6.39 (d, J = 1.8 Hz, 1H), 4.09-3.99 (m, 4H), 3.81-3.73 (m, 1H), 2.89 (d, J = 20.8 Hz, 2H), 1.41 (d, J = 7.2 Hz, 3H), 1.28-1.23 (m, 6H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 200.8 (d, J = 3.6 Hz), 142.7 (d, J = 12.2 Hz), 142.3 (d, J = 3.8 Hz), 118.8 (d, J = 8.8 Hz), 110.2 (d, J = 3.6 Hz), 62.4 (dd, J = 6.6, 5.0 Hz), 43.2 (d, J = 1.9 Hz), 25.4 (d, J = 144.0 Hz), 16.3 (d, J = 5.9 Hz), 14.1 (d, J = 2.0 Hz). IR (thin film): 2960, 1743, 1420, 1247 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{12}H_{19}O_5PNa$ 297.0867; Found 297.0855.

Diethyl[(3-(1-oxopropan-2-yl)thiophen-2-yl)methyl]phosphonate (11b). Yellow oil, 14 mg, 48% isolated yield. R_f = 0.33 (PE/EtOAc = 1:3). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.65 (d, J = 1.2 Hz, 1H), 7.22 (dd, J = 5.3, 2.5 Hz, 1H), 6.81 (d, J = 5.3 Hz, 1H), 4.11-4.03 (m, 4H), 3.90 (q, J = 7.1 Hz, 1H), 3.37 (d, J = 2.1 Hz, 1H), 3.32 (d, J = 2.1 Hz, 1H), 1.40 (d, J = 7.0 Hz, 3H), 1.28 (d, J = 7.3 Hz, 6H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 200.7 (d, J = 2.9 Hz), 136.1 (d, J = 8.8 Hz), 129.1 (d, J = 10.7 Hz), 126.9 (d, J = 3.8 Hz), 124.7 (d, J = 4.2 Hz), 62.7 (d, J = 6.9 Hz), 62.6 (d, J = 6.9 Hz), 46.4, 26.6 62.7 (d, J = 144.7 Hz), 16.5 (d, J = 5.9 Hz), 14.7. IR (thin film): 2985, 2935, 1728, 1030 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{12}H_{19}O_4PSNa$ 313.0639; Found 313.0685.

Diethyl[(2-(1-oxopropan-2-yl)furan-3-yl)methyl]-phosphonate (11c). Yellow oil, 8 mg, 29% isolated yield. R_f = 0.30 (PE/EtOAc = 1:3). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (d, J = 1.2 Hz, 1H), 7.33 (d, J = 1.8 Hz, 1H), 6.39 (s, 1H), 4.07-4.01 (m, 4H), 3.77 (q, J = 7.2 Hz, 1H), 2.89 (d, J = 20.8 Hz, 2H), 1.41 (d, J = 7.2 Hz, 3H), 1.26 (td, J = 7.1, 3.2 Hz, 6H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 198.8 (d, J = 3.4 Hz), 148.2 (d, J = 11.2 Hz), 142.3 (d, J = 1.4 Hz), 112.9 (d, J = 3.0 Hz), 112.3 (d, J = 9.7 Hz), 62.8 (t, J = 7.1 Hz), 45.0 (d, J = 1.9 Hz), 23.3 (d, J = 144.2 Hz), 16.5 (d, J = 5.9 Hz), 12.3 (d, J = 1.9 Hz). IR (thin film): 2960, 2935, 1420, 1247 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{12}H_{19}O_5PNa$ 297.0867; Found 297.0855.

Diethyl[(2-(1-oxopropan-2-yl)thiophen-3-yl)methyl]phosphonate (11d). Yellow oil, 16 mg, 54% isolated yield. R_f = 0.32 (PE/EtOAc = 1:3). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.62 (d, J = 1.6 Hz, 1H), 7.24 (s, 1H), 7.04 (dd, J = 5.2, 1.4 Hz, 1H), 4.08-3.99 (m, 4H), 3.72 (q, J = 7.0 Hz, 1H), 3.17 (d, J = 5.9 Hz, 1H), 3.12 (d, J = 5.9 Hz, 1H), 1.49 (d, J = 7.1 Hz, 3H), 1.27-1.24 (m, 7H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 199.3, 132.1 (d, J = 9.9 Hz), 130.2, 128.5 (d, J = 12.1 Hz), 124.3, 62.4, 46.2, 27.6 (d, J = 141.6 Hz), 16.4 (d, J = 5.9 Hz), 15.8. IR (thin film): 2980 2925, 1748, 1060 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{12}H_{19}O_4PSNa$ 313.0639; Found 313.0685.

Diethyl[(3-(1-oxopropan-2-yl)benzo[b]thiophen-2-yl)methyl]phosphonate (11e). Yellow oil, 9.5 mg, 56% isolated yield. R_f = 0.42 (PE/EtOAc = 1:3). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.82 (s, 1H), 7.82-7.77 (m, 1H), 7.54-7.47 (m, 1H), 7.34-7.29 (m, 2H), 4.16-4.04 (m, 6H), 3.45 (dq, J = 21.5, 15.7 Hz, 2H), 1.54 (d, J = 7.1 Hz, 3H), 1.34-1.25 (m, 6H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 201.7 (d, J = 3.0 Hz), 139.2, 138.4 (d, J = 3.5 Hz), 131.3 (d, J = 11.3 Hz), 130.3 (d, J = 9.7 Hz), 124.6, 124.5, 122.6, 122.2, 62.9 (d, J = 6.8 Hz), 62.7 (d, J = 6.8 Hz), 46.7 (d, J = 2.0 Hz), 27.7 (d, J = 143.5 Hz), 16.6 (d, J = 4.5 Hz), 13.0 (d, J = 2.2 Hz). IR (thin film): 2995, 2910, 1748, 1045 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{16}H_{21}O_4PSNa$ 363.0795; Found 363.0802.

Diethyl[(2-(1-oxopropan-2-yl)benzo[b]thiophen-3-yl)methyl]phosphonate (11f). Yellow oil, 7 mg, 29% isolated yield. R_f = 0.43 (PE/EtOAc = 1:3). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.81 (s, 1H), 7.81-7.77 (m, 1H), 7.53-7.48 (m, 1H), 7.32 (ddd, J = 5.8, 4.3, 1.9 Hz, 2H), 4.15-4.05 (m, 5H), 3.51-3.38 (m, 2H), 1.54 (d, J = 7.1 Hz, 3H), 1.34-1.26 (m, 6H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 201.7 (d, J = 3.0 Hz), 139.2 (d, J = 1.9 Hz), 138.4 (d, J = 3.6 Hz), 131.3 (d, J = 11.3 Hz), 130.3 (d, J = 9.6 Hz), 124.6 (d, J = 0.7 Hz), 124.5 (d, J = 1.4 Hz), 122.6 (d, J = 1.1 Hz), 122.3 (d, J = 1.3 Hz), 62.9 (d, J = 6.8 Hz), 62.7 (d, J = 6.8 Hz), 46.7 (d, J = 2.0 Hz), 27.6 (d, J = 143.5 Hz), 16.6 (d, J = 1.4 Hz), 16.5 (d, J = 1.4 Hz), 13.0 (d, J = 2.2 Hz). IR (thin film): 2990, 2925, 1728, 1030 cm^{-1}. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{16}H_{21}O_4PSNa$ 363.0795; Found 363.0802.

***N*-Cyclohexyl-2-[3-(1-oxopropan-2-yl)furan-2-yl]acetamide (11g).** Yellow oil, 83 mg, 63% isolated yield. R_f = 0.33 (PE/Et_2O = 2:8). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.60 (d, J = 1.1 Hz, 1H), 7.34 (d, J = 1.8 Hz, 1H), 6.22 (d, J = 1.8 Hz, 1H), 5.78 (br, 1H), 3.74-3.62 (m, 1H), 3.57-3.43 (m, 3H), 1.86-1.75 (m, 2H), 1.67-1.50 (m, 3H), 1.41-1.22 (m, 5H), 1.17-1.00 (m, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 201.0, 167.2, 146.2, 142.5, 118.8, 110.3, 48.5, 43.3, 34.9, 32.9, 32.9, 25.5, 24.8, 14.1 IR (thin film): 3296, 2929, 2854, 1644, 1538, 1450, 1350, 1249, 892, 736 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{15}H_{21}NO_3$ 263.1521; Found 263.1526.

Diethyl [(4-(1-oxopropan-2-yl)quinolin-3-yl)methyl)-phosphonate (11h). Yellow oil, 75 mg, 45% isolated yield. R_f = 0.10 (AcOEt = 100%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.89 (s, 1H), 8.81 (d, J = 1.6 Hz, 1H), 8.12 (d, J = 8.3 Hz, 1H), 7.74-7.60 (m, 2H), 7.58-7.43 (m, 1H), 4.33 (q, J = 7.0 Hz, 1H), 4.18-3.92 (m, 4H), 3.41 (dd, J = 21.7, 12.2 Hz, 2H), 1.66 (d, J = 7.0 Hz, 3H), 1.31 (t, J = 7.1 Hz, 3H), 1.21 (t, J = 7.1 Hz, 3H). ^{13}C{1H} NMR (101 MHz, $CDCl_3$) δ 202.2 (d, J = 2.2 Hz), 152.9 (d, J = 4.4 Hz), 148.1 (d, J = 2.8 Hz), 143.3 (d, J = 7.6 Hz), 130.8 (d, J = 1.3 Hz), 129.2 (d, J = 1.2 Hz), 127.5 (d, J = 0.9 Hz), 126.6 (d, J = 3.2 Hz), 124.7 (d, J = 9.7 Hz), 124.2 (d, J = 1.0 Hz), 62.9 (d, J = 7.0 Hz), 62.6 (d, J = 6.8 Hz), 48.8 (d, J = 1.6 Hz), 29.9 (d, J = 139.1 Hz), 16.5 (d, J = 5.6 Hz), 16.5 (d, J = 5.6 Hz), 14.0 (d, J = 1.1 Hz). IR (thin film): 2981, 2931, 2908, 1723, 1703, 1572, 1504, 1242, 1162, 1048, 1016, 958, 795, 763 cm^{-1}. HRMS (ESI) m/z: $[M]^+$ calcd for $C_{17}H_{22}NO_4P$ 335.1286; Found 335.1296.

General procedure for the ring-closing metathesis. To a solution of diene (0.2 mmol) in CH_2Cl_2 (4 mL) was added second generation Grubbs catalyst (0.01 mmol) and the resulting mixture was stirred at the indicated temperature using a heating mantle for the indicated amount of time. The reaction mixture was then filtered over a pad of Celite, concentrated under reduced pressure and the crude residue was purified by flash column chromatography.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the Publications website.

^{1}H and ^{13}C NMR spectra for all new compounds (PDF)

AUTHOR INFORMATION

Corresponding Authors

Stellios Arseniyadis – Queen Mary University of London, School of Biological and Chemical Sciences, Mile End Road, London, E1 4NS, UK; Email: s.arseniyadis@qmul.ac.uk

Laurent El Kaïm – Laboratoire de Synthèse Organique, CNRS, Ecole Polytechnique, ENSTA ParisTech, UMR 7652, Université Paris-Saclay, 828 Bd des Maréchaux, 91128 Palaiseau, France; Email: laurent.elkaim@ensta-paristech.fr

Authors

Mansour Dolé Kerim – Laboratoire de Synthèse Organique, CNRS, Ecole Polytechnique, ENSTA ParisTech, UMR 7652, Université Paris-Saclay, 828 Bd des Maréchaux, 91128 Palaiseau, France

Tania Katsina – Queen Mary University of London, School of Biological and Chemical Sciences, Mile End Road, London, E1 4NS, UK

Martin Cattoen – Queen Mary University of London, School of Biological and Chemical Sciences, Mile End Road, London, E1 4NS, UK

Nicolas Fincias – Queen Mary University of London, School of Biological and Chemical Sciences, Mile End Road, London, E1 4NS, UK

Notes

The authors declare no competing financial interest.

ORCID

Martin Cattoen: 0000-0002-9343-5948
Stellios Arseniyadis: 0000-0001-6831-2631
Laurent El Kaïm: 0000-0001-5729-8010

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