DOI: 10.1002/ejoc.201001717

[1,5]-Hydride Transfer/Cyclization of *ortho*-Amino Alkynyl Fischer Carbene Complexes: A Useful Tool for the Synthesis of Quinoline Derivatives

José Barluenga,*[a] Martín Fañanás-Mastral,[a] Amadeo Fernández,[a] and Fernando Aznar[a]

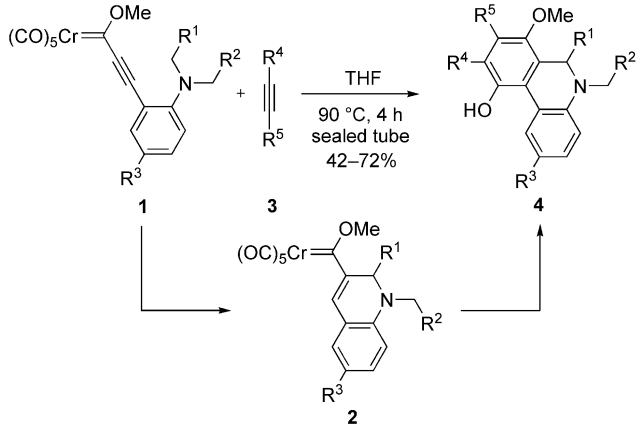
Keywords: Domino reactions / Carbenes / Chromium / Heterocycles / Hydride transfer

An efficient method for the synthesis of compounds containing a quinoline moiety by using *o*-aminophenyl alkynyl Fischer carbene complexes as starting materials is described. The reaction is based on a cascade process involving [1,5]-hydride transfer/cyclization to afford new alkenylcarbene complexes with quinoline moiety **2**. The reaction of alkenyl complexes **2** with unsaturated substrates such as electron-poor alkynes afford furo[2′,3′-3,4]cyclopenta[1,2-*c*]quinolinone derivatives **6** and (1,2-dihydroquinolin-3-ylvinyl)-malonates **12** when propiolic aldehydes and propiolates are used, respectively. The reactivity of the alkenylcarbene complexes was also studied by using 1,3-dienes to afford cyclohepta[*c*]quinolinones **17** when Danishefsky's diene is used and 3-pirimidinylquinoline derivatives **21** when 4-amino-1-azadienes are employed.

Introduction

Quinoline derivatives, such as 1,2-dihydroquinolines and 1,2,3,4-tetrahydroquinolines, are important structural components in naturally occurring alkaloids and synthetic analogues with interesting biological activities.[1] Therefore, the development of new and efficient synthetic routes for the preparation of their analogues is of importance to both synthetic organic chemistry and medicinal chemistry.[2,3] We have recently described a novel [1,5]-hydride transfer/cyclization process of *ortho*-amino alkynyl Fischer carbene complexes **1** that leads to 1,2-dihydroquinolynylcarbene complexes **2** (Scheme 1).[4] Considering the synthetic versatility of Fischer carbene complexes,[5] compounds **2** offer the possibility to manipulate the 1,2-dihydroquinoline moiety to introduce different functionalities or incorporate more complex cyclic systems to this structure. In our recent communication, we reported the reaction between chromium *ortho*-amino alkynyl Fischer carbene complexes **1** and alkynes **3**, which affords 5,6-dihydrophenantridine derivatives **4** through a novel [1,5]-hydride transfer/cyclization/Dötz benzannulation cascade process (Scheme 1).[4]

Encouraged by these results and aiming to evaluate the scope of the reaction, we next decided to explore the behavior of Fischer carbene complexes **1** with other unsaturated substrates. Herein we present some new cascade processes of chromium *ortho*-amino alkynyl Fischer carbene complexes which lead to the formation of different structures derived from the 1,2-dihydroquinoline core.



Scheme 1. Synthesis of 5,6-dihydrophenantridines **3** through a [1,5]-hydride transfer/cyclization/Dötz benzannulation cascade process.

Results and Discussion

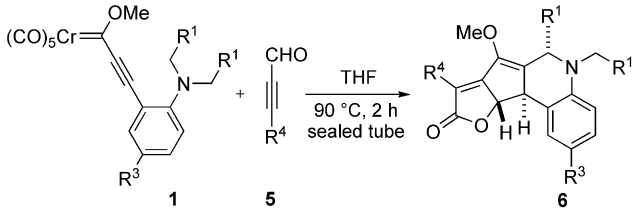
We decided to start studying the behavior of Fischer carbene complexes **1** with electron-deficient alkynes. The treatment of alkynylcarbene complexes **1** with propiolaldehydes **5** (6 equiv.) in THF at 90 °C in a sealed tube gave rise to bicyclic lactones **6** in good yield and with total diastereoselectivity (Table 1). The structure and the relative configuration of the stereogenic centers of new compounds **6** were determined by 1D and 2D NMR spectroscopic analysis and unequivocally ascertained by X-ray diffraction analysis carried out with compound **6d**.[6]

The formation of bicyclic lactones **6** can be explained as a result of the cascade process depicted in Scheme 2. Alkenylcarbene complex **2** formed from the 1,5-hydride transfer/cyclization process could undergo regioselective [2+2] cyclo-

[a] Instituto Universitario de Química Organometálica "Enrique Moles", Unidad Asociada al CSIC, Universidad de Oviedo, Julián Clavería 8, 33006 Oviedo, Spain
Fax: +34-985-103450
E-mail: barluenga@uniovi.es

Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/ejoc.201001717.

Table 1. Synthesis of bicyclic lactones **5**.



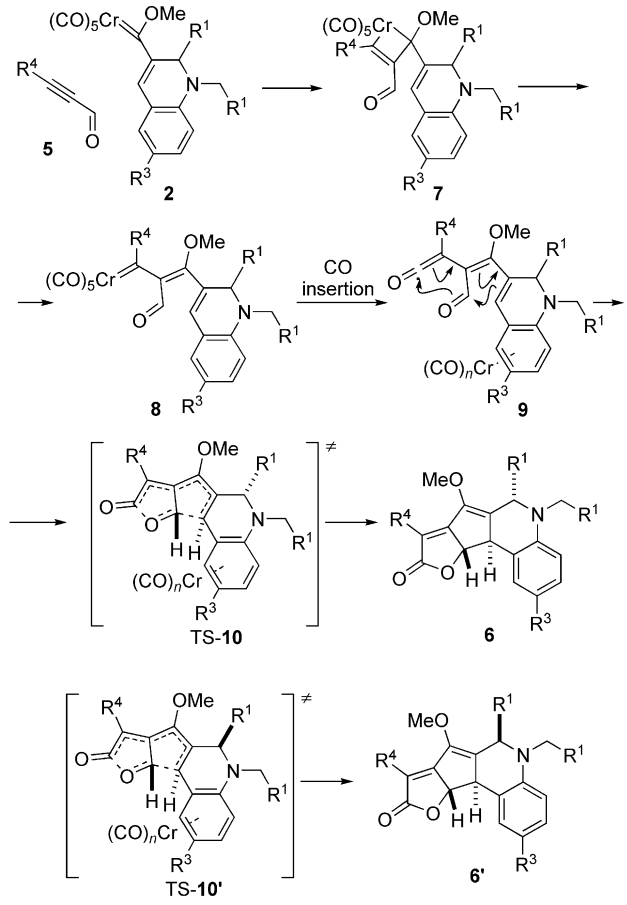
Carbene	R^1	R^3	Aldehyde	R^4	Product	Yield [%][a]
1a	4-MeC_6H_4	H	**5a**	TMS	**6a**	72
1a	4-MeC_6H_4	H	**5b**	Ph	**6b**	73
1a	4-MeC_6H_4	H	**5c**	C_5H_{11}	**6c**	61
1d	Ph	Cl	**5a**	TMS	**6d**	78
1d	Ph	Cl	**5b**	Ph	**6e**	75

[a] Isolated yield based on alkynylcarbene complex **1**.

addition of the propiolaldehyde to form intermediate **7**, followed by an electrocyclic ring-opening step to afford non-stabilized Fischer carbene complex **8**. Then, insertion of a carbonyl ligand would give rise to cross-conjugated ketene intermediate **9**, which would evolve through a van Halban–White-type double cyclization[7] to furo[2′,3′-3,4]cyclopenta[1,2-*c*]quinolinone derivatives **6**, after decoordination of the metal fragment. To understand the complete diastereoselectivity observed in compound **6**, we carried out DFT-based computational modeling of the van Halban–White double cyclization. According to our calculations, the cyclization takes place in an asynchronous concerted manner, in which the new C–O bond is highly developed in transition state TS-**10**. The formation of diastereoisomer **6** is clearly favored when compared with unobserved **6′**, which features the R^1 group in a *trans* relationship with the benzylic hydrogen atom. Indeed, an energy difference of 3.6 kcal/mol was obtained between both transition states TS-**10** and TS-**10′**. This energy difference can be understood by inspection of the molecular models. In TS-**10**, the steric interactions between R^1 and the rest of the molecule are minimized when compared with TS-**10′** (Scheme 2). A more detailed discussion is provided in the Supporting Information.

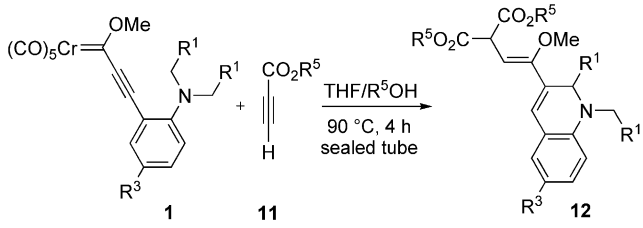
We then turned our attention to other electron-deficient alkynes such as propiolates **11**. When alkynyl Fischer carbene complexes **1** were treated with this type of alkynes in a 1:6 molar ratio using a 9:1 mixture of THF/R^5OH under the same reaction conditions as those described above, we could isolate, after workup, 1,2-dihydroquinoline derivatives **12** as single diastereoisomers in good yields (Table 2).[8]

The structure of 1,2-dihydroquinolines **12** was determined by 1D and 2D NMR spectroscopic analysis. The stereochemistry of the double bond was determined by a NOESY experiment carried out with compound **12a**, showing two determinant cross-peaks. One cross-peak appears between the α-hydrogen atom of the 1,3-dicarbonyl moiety H^a (δ = 4.55 ppm) and the methyl group of the methoxy group in the enol ether (δ = 3.48 ppm) and the other between one hydrogen of the enol ether moiety H^b (δ = 5.21 ppm) and the hydrogen over the C-4 of the quinoline moiety H^c (δ = 6.81 ppm, Figure 1).



Scheme 2. Proposed mechanism for the formation of compounds **6**.

Table 2. Synthesis of 1,2-dihydroquinolines **12**.



Carbene	R^1	R^3	Propiolate	R^5	Product	Yield [%][a]
1a	4-MeC_6H_4	H	**11a**	Me	**12a**	78
1a	4-MeC_6H_4	H	**11b**	Et	**12b**	79
1b	Ph	Me	**11c**	Me	**12c**	73
1a	4-MeC_6H_4	H	**11d**	allyl	**12d**	81

[a] Isolated yield based on alkynylcarbene complex **1**.

To explain this different chemical behavior observed in the reaction of carbene complexes **1** with propiolic esters, we proposed a mechanism to account for the formation of

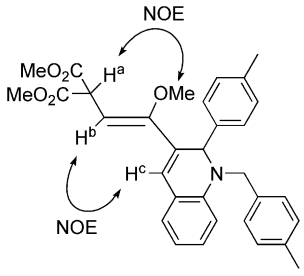
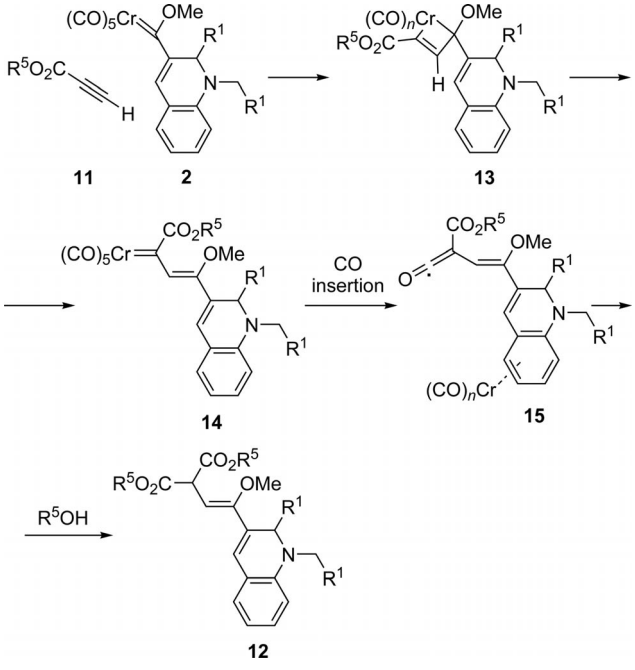


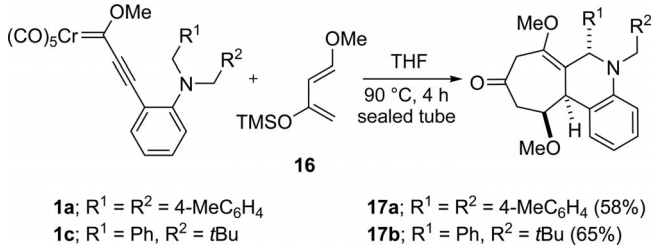
Figure 1. Determinant NOEs in compound **12a**.

compounds **12** shown in Scheme 3. Alkenylcarbene complexes **2** initially formed through 1,5-hydride transfer/cyclization could undergo regioselective [2+2] cyclization with one molecule of propiolate to give intermediates **13**. In this case, the regiochemistry of the insertion is the opposite to that observed in the case where propargylic aldehydes were used, probably due to the use of a terminal alkyne moiety. Subsequent electrocyclic ring opening would afford carbene complexes **14** as the *Z* isomer, avoiding the steric hindrance between the metal fragment and the quinoline moiety. Complexes **14** could further undergo a CO insertion reaction to furnish ketene intermediates **15**. Finally, nucleophilic attack of a molecule of alcohol would lead to the formation of (1,2-dihydroquinolin-3-ylvinyl)malonates **12**, after metal decoordination.[8]



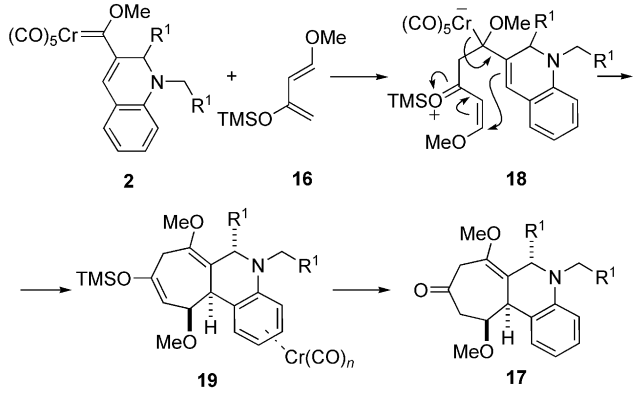
Scheme 3. Proposed mechanism for the formation of (1,2-dihydroquinolin-3-ylvinyl)malonates **12**.

Dienic systems are also good substrates for the reaction with alkenyl Fischer carbene complexes.[9] Thus, we tried to develop cascade processes in the presence of such unsaturated substrates. As a first approach, we decided to start our studies by employing electron-rich dienes, and we chose Danishefsky's diene **16**. Although this diene reacts with alkynyl Fischer carbene complex through a [4+2] cycloaddition reaction,[10] we observed that complexes **1** do not react with Danishefsky's diene **16** at room temperature. This fact allowed us to carry out the one-pot reaction without observing any side product derived from the reaction of the alkynylcarbene complex and the diene. Thus, when alkynylcarbene complexes **1** and Danishefsky's diene **16** were dissolved in THF and heated at 90 °C in a sealed tube, we obtained, after workup, tetrahydrocyclohepta[*c*]quinolinones **17** in good yields and with total diastereoselectivity (Scheme 4). Formation of compounds **17** can be considered as a [1,5]-hydride transfer/cyclization/[4+3] cycloaddition cascade process.



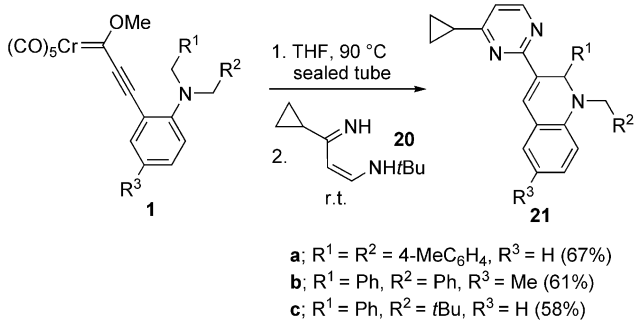
Scheme 4. Synthesis of tetrahydrocyclohepta[*c*]quinolinones **17** through a [1,5]-hydride transfer/cyclization/[4+3] cycloaddition cascade process.

The formation of compound **17** could be explained through the mechanism depicted in Scheme 5. Thus, the reaction would start with 1,2 nucleophilic addition of the terminal carbon of the enol ether moiety of the dienic system to alkenylcarbene complex **2** to form zwitterionic intermediate **18**. This intermediate could undergo intramolecular Michael addition of the allylchromate to the unsaturated oxonium moiety to afford seven-membered intermediate **19**. The approach of the unsaturated oxonium moiety to the allylchromate from the opposite face to where the R^1 group on the quinoline moiety is placed could be responsible for the resulting complete diastereoselectivity. Further hydrolysis and metal decoordination furnish tetrahydrocycloheptaquinolinones **17**. Alternatively, the reaction to form **17** could first give a cyclopropane intermediate and then undergo Cope rearrangement.[9d,11]



Scheme 5. Proposed mechanism for the reactivity of alkenyl complexes **6** and electron-rich dienes to give tetrahydrocycloheptaquinolinones **17**.

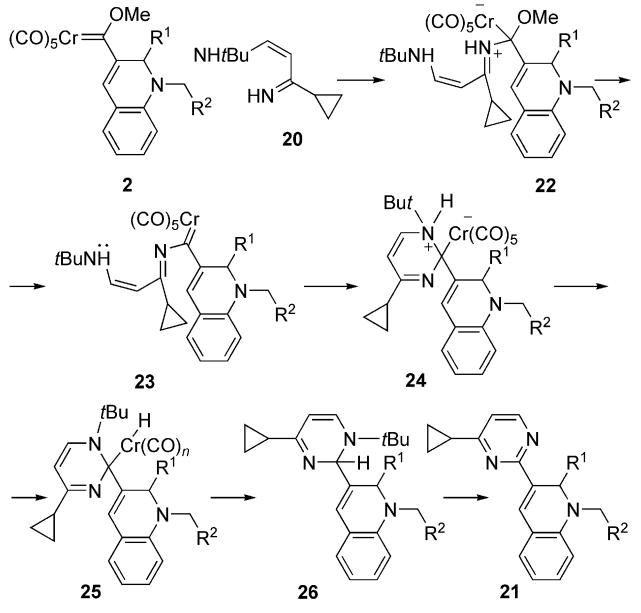
We were also able to accomplish a cascade process of alkynylcarbene complexes **1** by using electron-poor dienes such as 4-amino-1-azadienes **20**. As alkynyl Fischer carbene complexes react at low temperatures with this type of heterodiene,[12] first we had to develop the [1,5]-hydride transfer/cyclization at 90 °C, and then, cool the reaction mixture to room temperature and add the heterodiene. After workup of the reaction, we obtained 3-pyrimidinylquinoline derivatives **21** in good yields (Scheme 6).[13] This transformation can be considered as a formal [1,5]-hydride transfer/cyclization/[5+1] cycloaddition cascade process.



Scheme 6. Synthesis of 3-pirimidinylquinoline derivatives **21** through a [1,5]-hydride transfer/cyclization/[5+1] cycloaddition cascade process.

The formation of compounds **21** can be explained by the reaction of alkenylcarbene complexes **2** generated in the first step of the transformation with aminoazadiene **20**. It is important to note that the behavior of carbene complexes **2** is completely different than that of standard α,β-unsaturated Fischer carbene complexes, which afford azepines in their reaction with 4-amino-1-azadienes.[14]

In Scheme 7 we propose a tentative mechanism that accounts for the formation of 3-pirimidinylquinoline derivatives.[15] We assume first that 1,2-nucleophilic addition of the iminic nitrogen atom of aminoazadiene **20** to carbene complex **2** occurs, which gives rise to zwitterionic intermediate **22**. In the following step, intermediate **22** would evolve into imino carbene complex **23** by elimination of a molecule of methanol. This complex would experience nucleophilic intramolecular attack of the enaminic nitrogen atom to give chromate complex **24**. 1,3-Hydrogen shift, giving hydridechromium complex **25**, followed by reductive elimination would furnish dihydropyrimidine derivative **26**. A final aromatization step would lead to the formation of 3-pyrimidinylquinoline derivative **21**.



Scheme 7. Proposed mechanism for the formation of 3-pyrimidinylquinoline derivatives **21**.

Conclusions

In conclusion, we have described a new and efficient method for the synthesis of quinoline derivatives from easily available *o*-benzylaminophenylalkynylchromiumcarbene complexes and alkyne or diene derivatives. The reaction is based on an original [1,5]-hydride transfer/cyclization/[3+2], [4+2], or [5+1] cascade process. Using this strategy, highly substituted phenantridines, furo[2′,3′-3,4]cyclopenta[1,2-*c*]-quinolinones, (1,2-dihydroquinolin-3-ylvinyl)malonates, tetrahydrocyclohepta[*c*]quinolinones, and 3-pyrimidinylquinoline derivatives are easily available in a simple way. Moreover, the quinoline systems obtained through this strategy are nature-like structural motifs that might be of value in the discovery of biologically active molecular agents.

Experimental Section

General Methods: ^{1}H NMR spectra were recorded with a Bruker AV-600 (600 MHz), Bruker AMX-400 (400 MHz), or Bruker DPX-300 (300 MHz). Chemical shifts are reported in ppm from tetramethylsilane with the residual solvent resonance as the internal standard ($CHCl_3$: δ = 7.26 ppm). Data are reported as follows: chemical shift, multiplicity (s: singlet, d: doublet, dd: double doublet, td: triplet of doublets, t: triplet, q: quartet, br.: broad, m: multiplet), coupling constants (*J* in Hz), integration, and assignment. ^{13}C NMR spectra were recorded with a Bruker AV-600 (150 MHz), Bruker AMX-400 (100 MHz), or Bruker DPX-300 (75 MHz) with complete proton decoupling. Chemical shifts are reported in ppm from tetramethylsilane with the solvent resonance as internal standard ($CDCl_3$: δ = 76.95 ppm). 2D NMR experiments (COSY, HSQCED, HMBC, and NOESY) were recorded with a Bruker AMX-400 (400 MHz). High-resolution mass spectrometry was carried out with a Finnigan-Mat 95 spectrometer. All reactions were conducted in dried glassware under an inert atmosphere of argon. Tetrahydrofuran used as solvent was dried and deoxygenated with a PureSolv column system before used.

General Procedure for the Synthesis of Bicyclic Lactone Derivatives 6: A solution of alkynyl carbene complex **1** (0.5 mmol) and aldehyde **5** (3 mmol) in THF (10 mL) was heated in a sealed tube under an argon atmosphere at 90 °C for 4 h. Then, the reaction was allowed to reach room temperature, hexane (30 mL) was added, and the mixture was exposed to air and light. Finally, the mixture was filtered through a pad of Celite, solvents were removed under reduced pressure, and the crude product was purified by column

chromatography on silica gel (hexane/ethyl acetate, 7:1) to afford lactones **6**.

(6*S,10a*S**,10b*R**)-7-Methoxy-5-(4-methylbenzyl)-6-(4-methylphenyl)-8-(trimethylsilyl)-10a,10b-dihydro-5*H*-furo[2′,3′-3,4]cyclopenta[1,2-*c*]quinolin-9(6*H*)-one (6a):** Yield: 72%. Colorless oil. R_f = 0.35 (hexane/AcOEt, 7:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.15 (d, J = 7.6 Hz, 1 H), 7.30 (d, J = 7.6 Hz, 2 H), 7.15 (d, J = 7.6 Hz, 2 H), 7.13 (t, J = 7.8 Hz, 1 H), 6.99 (d, J = 8.2 Hz, 2 H), 6.96 (d, J = 8.2 Hz, 2 H), 6.91 (t, J = 7.4 Hz, 1 H), 6.70 (t, J = 8.1 Hz, 1 H), 5.60 (s, 1 H), 5.47 (s, 1 H), 4.55 (d, J = 14.8 Hz, 1 H), 4.34 (d, J = 14.8 Hz, 1 H), 3.32 (s, 3 H), 2.85–2.77 (m, 2 H), 2.75–2.66 (m, 2 H), 2.36 (s, 3 H), 2.25 (s, 3 H), 1.30 (t, J = 7.3 Hz, 1 H), 1.23 (t, J = 7.3 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.6 (C), 147.0 (C), 145.4 (C), 136.9 (C), 136.8 (C), 136.7 (C), 135.5 (C), 135.0 (C), 131.1 (C), 129.4 (C), 129.3 (2 CH), 128.8 (2 CH), 128.3 (CH), 127.9 (2 CH), 127.6 (2 CH), 125.5 (CH), 123.8 (C), 118.5 (CH), 117.6 (C), 115.3 (CH), 61.8 (NCH), 59.1 (OCH_3), 53.1 (NCH_2), 21.2 (CH_3), 21.1 (CH_3), 20.1 (CH_2), 20.0 (CH_2), 15.7 (CH_3), 14.5 (CH_3) ppm. HRMS (EI): calcd. for $C_{33}H_{35}NO_3Si$ 521.2386; found 521.2389.

(6*S,10a*S**,10b*R**)-7-Methoxy-5-(4-methylbenzyl)-6-(4-methylphenyl)-8-phenyl-10a,10b-dihydro-5*H*-furo[2′,3′-3,4]cyclopenta-[1,2-*c*]quinolin-9(6*H*)-one (6b):** Yield: 73%. Colorless Oil. R_f = 0.32 (hexane/AcOEt, 7:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.81–7.71 (m, 2 H), 7.49 – 7.32 (m, 4 H), 7.22–7.09 (m, 9 H), 6.82 (t, J = 7.3 Hz, 1 H), 6.70 (d, J = 8.3 Hz, 1 H), 5.53 (s, 1 H), 5.25 (d, J = 3.9 Hz, 1 H), 4.72 (d, J = 17.1 Hz, 1 H), 4.32 (d, J = 17.1 Hz, 1 H), 3.88 (d, J = 3.8 Hz, 1 H), 3.58 (s, 3 H), 2.35 (s, 3 H), 2.34 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.6 (C), 160.5 (C), 145.8 (C), 144.1 (C), 138.0 (C), 137.5 (C), 136.7 (C), 134.6 (C), 132.4 (C), 129.8 (C), 129.7 (2 CH), 129.4 (2 CH), 128.8 (C), 128.7 (CH), 128.6 (2 CH), 128.4 (2 CH), 128.3 (CH), 126.4 (2 CH), 126.1 (2 CH), 120.8 (C), 119.2 (C), 117.5 (CH), 112.0 (CH), 87.8 (CH), 60.6 (OCH_3), 58.2 (NCH), 53.0 (NCH_2), 43.5 (CH_3), 21.1 (CH_3), 21.0 (CH_3) ppm. HRMS (EI): calcd. for $C_{36}H_{31}NO_3$ 525.2304; found 525.2298.

(6*S,10a*S**,10b*R**)-7-Methoxy-5-(4-methylbenzyl)-6-(4-methylphenyl)-8-pentyl-10a,10b-dihydro-5*H*-furo[2′,3′-3,4]cyclopenta-[1,2-*c*]quinolin-9(6*H*)-one (6c):** Yield: 61%. Colorless oil. R_f = 0.30 (hexane/AcOEt, 7:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.37 (d, J = 7.4 Hz, 1 H), 7.18–7.06 (m, 9H), 6.78 (t, J = 7.0 Hz, 1 H), 6.65 (d, J = 8.3 Hz, 1 H), 5.44 (s, 1 H), 5.11 (d, J = 4.0 Hz, 1 H), 4.68 (d, J = 17.2 Hz, 1 H), 4.28 (d, J = 17.2 Hz, 1 H), 3.83 (s, 2 H), 3.68 (d, J = 3.7 Hz, 1 H), 2.35 (s, 3 H), 2.31 (s, 3 H), 1.67–1.16 (m, 8 H), 0.86 (t, J = 7.2 Hz, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 175.5 (C), 160.9 (C), 145.7 (C), 144.1 (C), 138.2 (C), 137.3 (C), 136.6 (C), 134.6 (C), 129.5 (2 CH), 129.4 (CH), 129.3 (2 CH), 128.5 (CH), 128.2 (CH), 126.3 (CH), 126.0 (CH), 121.1 (C), 212.0 (CH), 117.3 (CH), 111.8 (CH), 88.0 (CH), 60.2 (OCH_3), 58.2 (NCH), 52.9 (NCH_2), 43.2 (CH), 31.4 (CH_2), 27.8 (C), 24.9 (C), 22.3 (CH_2), 21.0 (2 CH_3), 13.9 (CH_3) ppm. HRMS (EI): calcd. for $C_{35}H_{36}ClNO_3$ 553.2384; found 553.2384.

(6*S,10a*S**,10b*R**)-5-Benzyl-2-chloro-7-methoxy-6-phenyl-8-(trimethylsilyl)-10a,10b-dihydro-5*H*-furo[2′,3′-3,4]cyclopenta[1,2-*c*]-quinolin-9(6*H*)-one (6d)**Yield: 78%. White solid. M.p. 146–158 °C. R_f = 0.36 (hexane/AcOEt, 7:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.49–7.04 (m, 10 H), 6.64 (d, J = 8.9 Hz, 1 H), 5.53 (s, 1 H), 5.06 (d, J = 4.0 Hz, 1 H), 4.76 (d, J = 17.0 Hz, 1 H), 4.35 (d, J = 17.0 Hz, 1 H), 3.80 (s, 3 H), 0.34 (s, 9 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.4 (C), 175.9 (C), 147.2 (C), 142.5 (C), 140.3 (C), 137.2 (C), 132.2 (C), 129.0 (2 CH), 128.8 (2 CH), 128.5 (CH), 128.1 (CH), 127.8 (CH), 127.3 (CH), 126.4 (2 CH), 126.0 (2 CH), 122.8 (C), 122.6 (C), 120.7 (C), 113.5 (CH), 89.7 (CH), 60.4 (OCH_3), 58.2 (NCH), 53.8 (NCH_2), 43.3 (CH), –1.3 [Si-(CH_3)$_3$] ppm. HRMS (EI): calcd. for $C_{31}H_{31}NO_3$ 477.2662; found 465.2663.

(6*S,10a*S**,10b*R**)-5-Benzyl-2-chloro-7-methoxy-6,8-diphenyl-10a,10b-dihydro-5*H*-furo[2′,3′-3,4]cyclopenta[1,2-*c*]quinolin-9(6*H*)-one (6e):** Yield: 75%. Colorless oil. R_f = 0.32 (hexane/AcOEt, 7:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.77–7.73 (m, 2 H), 7.58–7.19 (m, 13 H), 6.62 (d, J = 8.9 Hz, 1 H), 5.56 (s, 1 H), 5.23 (d, J = 4.0 Hz, 1 H), 4.73 (d, J = 17.3 Hz, 1 H), 4.36 (d, J = 17.3 Hz, 1 H), 3.82 (d, J = 4.1 Hz, 1 H), 3.60 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.2 (C), 159.7 (C), 146.2 (C), 142.6 (C), 140.6 (C), 137.2 (C), 131.8 (C), 131.6 (C), 130.8 (C), 130.6 (C), 130.0 (C), 129.1 (2 CH), 128.8 (2 CH), 128.7 (CH), 128.6 (CH), 128.6 (2 CH), 128.4 (2 CH), 128.1 (CH), 128.0 (CH), 126.3 (2 CH), 126.0 (2 CH), 122.28 (CH), 113.37 (CH), 87.35 (CH), 60.62 (OCH_3), 58.57 (NCH), 53.69 (NCH_2), 43.31 (CH) ppm. HRMS (EI): calcd. for $C_{34}H_{26}ClNO_3$ 531.1601; found 531.1612.

General Procedure for the Synthesis of 1,2-Dihydroquinolines 12: A solution of alkynyl carbene complex **1** (0.5 mmol) and the corresponding propiolate **11** (3 mmol) in THF (9 mL) and R^5OH (1 mL) was heated in a sealed tube under an argon atmosphere at 90 °C for 4 h. Then, the reaction was allowed to reach room temperature, hexane (30 mL) was added, and the mixture was exposed to air and light. Finally, the mixture was filtered through a pad of Celite, the solvents were removed under reduced pressure, and the crude product was purified by column chromatography on silica gel (hexane/ethyl acetate, 5:1) to afford 1,3-dicarbonyl compounds **12**.

(*Z*)-Dimethyl 2-{2-methoxy-2-[1-(4-methylbenzyl)-2-(4-methylphenyl)-1,2-dihydroquinolin-3-yl]vinyl}malonate (12a): Yield: 46%. Yellow oil. R_f = 0.29 (hexane/AcOEt, 5:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.18 (d, J = 7.8 Hz, 2 H), 7.13 (d, J = 7.9 Hz, 4H), 7.08 (d, J = 7.2 Hz, 1 H), 7.05–7.02 (m, 3 H), 6.81 (s, 1 H), 6.66 (t, J = 7.3 Hz, 1 H), 6.46 (d, J = 8.1 Hz, 1 H), 5.21 (d, J = 9.2 Hz, 1 H), 5.18 (s, 1 H), 4.56 (d, J = 9.2 Hz, 1 H), 4.51 (d, J = 16.1 Hz, 1 H), 4.20 (d, J = 16.1 Hz, 1 H), 3.72 (s, 3 H), 3.65 (s, 3 H), 3.48 (s, 3 H), 2.35 (s, 3 H), 2.30 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ =168.6 (C), 168.6 (C), 156.2 (C), 144.0 (C), 137.8 (C), 137.4 (C), 136.7 (C), 134.3 (C), 130.0 (CH), 129.3 (2 CH), 129.0 (2 CH), 128.7 (C), 128.2 (CH), 127.0 (2 CH), 126.8 (2 CH), 124.7 (CH), 121.5 (C), 116.9 (CH), 111.2 (CH), 106.2 (CH), 62.7 (CH), 59.3 (CH_3), 52.7 (CH_3), 52.6 (CH_3), 51.6 (CH_2), 49.0 (CH), 21.1 (2 CH_3) ppm. HRMS (EI): calcd. for $C_{32}H_{33}NO_5$ 511.2353; found 511.2370.

(*Z*)-Diethyl 2-{2-methoxy-2-[1-(4-methylbenzyl)-2-(4-methylphenyl)-1,2-dihydroquinolin-3-yl]vinyl}malonate (12b): Yield: 51%. Yellow oil. R_f = 0.39 (hexane/AcOEt, 5:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.18 (d, J = 7.9 Hz, 2 H), 7.12 (d, J = 7.9 Hz, 4 H), 7.08 (d, J = 7.5 Hz, 1 H), 7.03–7.01 (m, 3 H), 6.83 (s, 1 H), 6.66 (t, J = 7.3 Hz, 1 H), 6.45 (d, J = 8.2 Hz, 1 H), 5.22 (d, J = 9.3 Hz, 1 H), 5.17 (s, 1 H), 4.52 (d, J = 9.3 Hz, 1 H), 4.50 (d, J = 16.0 Hz, 1 H), 4.21 (d, J = 16.0 Hz, 1 H), 4.18 (q, J = 7.1 Hz, 2 H), 4.09 (q, J = 7.1 Hz, 2 H), 3.49 (s, 3 H), 2.34 (s, 3 H), 2.28 (s, 3 H), 1.24 (t, J = 7.1 Hz, 3 H), 1.13 (t, J = 7.1 Hz, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ =168.2 (C), 168.2 (C), 156.0 (C), 143.9 (C), 137.7 (C), 137.4 (C), 136.7 (C), 134.3 (C), 129.9 (CH), 129.3 (2 CH), 129.1 (2 CH), 128.7 (C), 128.2 (CH), 127.0 (2 CH), 126.8 (2 CH), 124.5 (CH), 121.6 (C), 116.9 (CH), 111.3 (CH), 106.6 (CH), 62.6 (CH), 61.6 (CH_2), 61.5 (CH_2), 59.5 (CH_3), 51.6 (CH_2), 49.5 (CH), 21.1 (2 CH_3), 14.0 (CH_3), 13.8 (CH_3) ppm. HRMS (EI): calcd. for $C_{34}H_{37}NO_5$ 539.2666; found 539.2665.

(*Z*)-Dimethyl 2-[2-(1-benzyl-2-phenyl-1,2-dihydroquinolin-3-yl)-2-methoxyvinyl]malonate (12c): Yield: 48%. Yellow oil. R_f = 0.27 (hexane/AcOEt, 5:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.33–7.25 (m, 5 H), 7.23–7.20 (m, 5 H), 6.92 (d, *J* = 1.4 Hz, 1 H), 6.85 (dd, *J* = 8.2, 1.4 Hz, 1 H), 6.80 (s, 1 H), 6.36 (d, *J* = 8.2 Hz, 1 H), 5.20 (d, *J* = 9.4 Hz, 1 H), 5.18 (s, 1 H), 4.55 (d, *J* = 9.4 Hz, 1 H), 4.51 (d, *J* = 16.3 Hz, 1 H), 4.25 (d, *J* = 16.3 Hz, 1 H), 3.72 (s, 3 H), 3.63 (s, 3 H), 3.47 (s, 3 H), 2.24 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ =168.6 (C), 168.5 (C), 156.1 (C), 141.7 (C), 140.7 (C), 137.6 (C), 130.5 (CH), 128.8 (CH), 128.7 (C), 128.6 (2 CH), 128.4 (2 CH), 127.8 (CH), 127.0 (2 CH), 126.8 (2 CH), 126.1 (C), 124.8 (CH), 121.5 (C), 111.3 (CH), 106.3 (CH), 63.2 (CH), 59.3 (CH_3), 52.7 (CH_3), 52.6 (CH_3), 52.2 (CH_2), 49.0 (CH), 20.2 (CH_3) ppm. HRMS (EI): calcd. for $C_{31}H_{30}NO_5$ $[M - H]^+$ 496.2118; found 496.2113.

(*Z*)-Diallyl 2-{2-Methoxy-2-[1-(4-methylbenzyl)-2-(*p*-tolyl)-1,2-dihydroquinolin-3-yl]vinyl}malonate (12d): Yield: 57%. Yellow oil. R_f = 0.44 (hexane/AcOEt, 5:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.18 (d, *J* = 8.0 Hz, 2 H), 7.14–7.05 (m, 6 H), 7.01 (d, *J* = 7.9 Hz, 2 H), 6.83 (s, 1 H), 6.66 (t, *J* = 7.4 Hz, 1 H), 6.46 (d, *J* = 8.2 Hz, 1 H), 5.87 (ddt, *J* = 17.1, 10.5, 5.6 Hz, 1 H), 5.76 (ddt, *J* = 17.2, 10.5, 5.6 Hz, 1 H), 5.30 (dd, *J* = 17.2, 1.4 Hz, 1 H), 5.24 (d, *J* = 9.2 Hz, 1 H), 5.25–5.19 (m, 3 H), 5.17 (s, 1 H), 4.62 (d, *J* = 5.6 Hz, 2 H), 4.61 (d, *J* = 9.3 Hz, 1 H), 4.54 (d, *J* = 5.6 Hz, 2 H), 4.50 (d, *J* = 16.1 Hz, 1 H), 4.20 (d, *J* = 16.1 Hz, 1 H), 3.50 (s, 3 H), 2.35 (s, 3 H), 2.29 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ =167.8 (C), 167.7 (C), 156.3 (C), 143.9 (C), 137.6 (C), 137.4 (C), 136.7 (C), 134.3 (C), 131.6 (CH), 131.5 (CH), 129.9 (CH), 129.3 (2 CH), 129.1 (2 CH), 128.6 (C), 128.2 (CH), 127.0 (2 CH), 126.7 (2 CH), 124.7 (CH), 121.6 (C), 118.4 (CH_2), 118.3 (CH_2), 116.9 (CH), 111.3 (CH), 106.1 (CH), 66.1 (CH_2), 66.0 (CH_2), 62.6 (CH), 59.4 (CH_3), 51.6 (CH_2), 49.3 (CH), 21.1 (2 CH_3) ppm. HRMS (EI): calcd. for $C_{36}H_{37}NO_5$ 563.2672; found 563.2673.

General Procedure for the Synthesis of Compounds 17: A solution of alkynyl carbene complex **1** (0.5 mmol) and Danishefsky's diene **16** (1.5 mmol) in THF (10 mL) was heated in a sealed tube under an argon atmosphere at 90 °C for 4 h. Then, the reaction was allowed to reach room temperature and hydrolyzed by adding SiO_2. Finally, the solvents were removed under reduced pressure, and the crude product was purified by column chromatography on silica gel (hexane/ethyl acetate 7:1) to afford compounds **17**.

(11*S,11a*R**)-7,11-Dimethoxy-5-(4-methylbenzyl)-6-(4-methylphenyl)-8,10,11,11a-tetrahydro-5*H*-cyclohepta[*c*]quinolin-9(6*H*)-one (17a):** Yield: 48%. Brown oil. R_f = 0.39 (hexane/AcOEt, 3:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.18–7.00 (m, 10 H), 6.70 (td, *J* = 7.4, 0.8 Hz, 1 H), 6.68 (d, *J* = 8.2 Hz, 1 H), 5.70 (s, 1 H), 4.69 (d, *J* = 16.5 Hz, 1 H), 4.21 (d, *J* = 16.5 Hz, 1 H), 4.15 (td, *J* = 7.1, 3.2 Hz, 1 H), 3.61 (d, *J* = 3.2 Hz, 1 H), 3.58 (dd, *J* = 8.6, 7.1, Hz, 1 H), 3.51 (dd, *J* = 8.6, 7.1 Hz, 1 H), 3.38 (s, 3 H), 2.80 (s, 3 H), 2.75 (d, *J* = 6.7 Hz, 1 H), 2.33 (s, 3 H), 2.33 (d, *J* = 6.7 Hz, 1 H), 2.29 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ =206.3 (C), 145.5 (C), 145.1 (C), 139.5 (C), 136.3 (C), 135.5 (C), 135.4 (C), 129.2 (2 CH), 128.1 (2 CH), 127.7 (2 CH), 127.6 (CH), 127.5 (CH), 126.8 (2 CH), 121.3 (C), 121.1 (C), 116.6 (CH), 112.1 (CH), 81.9 (CH), 58.6 (CH), 57.1 (CH_3), 56.4 (CH_3), 53.2 (CH_2), 46.3 (CH_2), 45.0 (CH_2), 41.7 (CH), 21.1 (2 CH_3) ppm. HRMS (EI): calcd. for $C_{31}H_{33}NO_3$ 467.2460; found 467.2463.

(11*S,11a*R**)-7,11-Dimethoxy-5-neopentyl-6-phenyl-8,10,11,11a-tetrahydro-5*H*-cyclohepta[*c*]quinolin-9(6*H*)-one (17b):** Yield: 65%. Brown oil. R_f = 0.50 (hexane/AcOEt, 3:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.18–7.05 (m, 7 H), 6.98 (d, *J* = 8.3 Hz, 1 H), 6.63 (t, *J* = 7.3 Hz, 1 H), 5.87 (s, 1 H), 4.10 (td, *J* = 7.1, 3.4 Hz, 1 H), 3.74 (d, *J* = 15.1 Hz, 1 H), 3.63 (s, 3 H), 3.57 (d, *J* = 15.1 Hz, 1 H), 3.54–3.50 (m, 2 H), 2.74 (d, *J* = 6.8 Hz, 1 H), 2.71 (d, *J* = 6.8 Hz, 1 H), 1.00 (s, 9 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ =206.2 (C), 146.4 (C), 144.4 (C), 142.1 (C), 127.6 (CH), 127.4 (2 CH), 127.3 (2 CH), 127.0 (CH), 125.5 (CH), 120.4 (C), 120.4 (C), 115.7 (CH), 112.0 (CH), 82.1 (CH), 60.3 (CH_2), 59.1 (CH), 57.1 (CH_3), 56.4 (CH_3), 46.4 (CH_2), 44.7 (CH_2), 40.8 (CH), 35.1 (C), 28.2 (3 CH_3) ppm. HRMS (EI): calcd. for $C_{27}H_{33}NO_3$ 419.2460; found 419.2451.

General Procedure for the Synthesis of 1,2-Dihydroquinoline Derivatives 21: A solution of alkynyl carbene complex **1** (0.5 mmol) and azadiene **20** (3 mmol) in THF (10 mL) was heated in a sealed tube under an argon atmosphere at 90 °C for 2 h. Then, the reaction was allowed to reach room temperature, and the azadiene (3 mmol) was added. The mixture was stirred at room temperature until complete loss of the characteristic carbene color (dark violet). Then, hexane (30 mL) was added, and the mixture was exposed to air and light. Finally, the mixture was filtered through a pad of Celite, the solvents were removed under reduced pressure, and the crude product was purified by column chromatography on silica gel (hexane/triethylamine, 10:1) to afford compounds **21**.

3-(4-Cyclopropylpyrimidin-2-yl)-1-neopentyl-2-phenyl-1,2-dihydroquinoline (21a): Yield: 59%. Yellow oil. R_f = 0.34 (hexane/NEt_3, 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.44 (d, *J* = 5.1 Hz, 1 H), 7.90 (s, 1 H), 7.35–7.33 (m, 2 H), 7.19–7.15 (m, 3 H), 7.13 (d, *J* = 8.4, 1.4 Hz, 1 H), 6.93 (d, *J* = 5.1 Hz, 1 H), 6.75 (d, *J* = 8.4 Hz, 1 H), 6.62 (t, *J* = 7.3 Hz, 1 H), 6.12 (s, 1 H), 3.54 (d, *J* = 15.1 Hz, 1 H), 2.98 (d, *J* = 15.1 Hz, 1 H), 1.97–1.90 (m, 1 H), 1.28–1.23 (m, 1 H), 1.18–1.13 (m, 1 H), 1.09–1.03 (m, 2 H), 1.02 (s, 9 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ =170.9 (C), 163.0 (C), 155.6 (CH), 146.3 (C), 142.5 (C), 131.9 (C), 130.1 (CH), 129.5 (CH), 129.4 (CH), 128.1 (2 CH), 127.3 (CH), 127.1 (2 CH), 122.3 (C), 116.3 (CH), 116.0 (CH), 112.0 (CH), 62.1 (CH), 57.8 (CH_2), 35.2 (C), 28.3 (3 CH_3), 16.9 (CH), 11.0 (CH_2), 10.9 (CH_2) ppm. HRMS (EI): calcd. for $C_{27}H_{29}N_3$ 395.2361; found 395.2370.

1-Benzyl-3-(4-cyclopropylpyrimidin-2-yl)-6-methyl-2-phenyl-1,2-dihydroquinoline (21b): Yield: 52%. Yellow oil. R_f = 0.31 (hexane/NEt_3, 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.40 (d, *J* = 5.1 Hz, 1 H), 8.00 (s, 1 H), 7.38–7.17 (m, 10 H), 7.08 (d, *J* = 1.8 Hz, 1 H), 6.88 (dd, *J* = 8.3, 1.8 Hz, 1 H), 6.87 (d, *J* = 5.1 Hz, 1 H), 6.36 (t, *J* = 8.3 Hz, 1 H), 5.98 (s, 1 H), 4.52 (d, *J* = 16.2 Hz, 1 H), 4.38 (d, *J* = 16.2 Hz, 1 H), 2.26 (s, 3 H), 1.90–1.82 (m, 1 H), 0.99–0.93 (m, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ =170.9 (C), 162.7 (C), 155.4 (CH), 142.7 (C), 141.8 (C), 138.0 (C), 132.8 (C), 131.1 (CH), 129.6 (CH), 129.0 (CH), 128.5 (2 CH), 128.1 (2 CH), 127.4 (2 CH + CH), 127.1 (2 CH), 126.8 (CH), 125.8 (C), 122.0 (C), 116.2 (CH), 111.5 (CH), 62.1 (CH), 52.2 (CH_2), 20.3 (CH_3), 16.9 (CH), 11.1 (CH_2), 10.6 (CH_2) ppm. HRMS (EI): calcd. for $C_{30}H_{27}N_3$ 429.2205; found 429.2210.

3-(4-Cyclopropylpyrimidin-2-yl)-1-(4-methylbenzyl)-2-(4-methylphenyl)-1,2-dihydroquinoline (21c): Yield: 67%. Yellow oil. R_f = 0.29 (hexane/NEt_3, 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.39 (d, *J* = 5.1 Hz, 1 H), 7.99 (s, 1 H), 7.26 (d, *J* = 7.9 Hz, 2 H), 7.23 (dd, *J* = 7.4, 1.5 Hz, 1 H), 7.21 (d, *J* = 7.9 Hz, 2 H), 7.12 (d, *J* = 7.9 Hz, 2 H), 7.05 (td, *J* = 7.8, 1.5 Hz, 1 H), 7.00 (d, *J* = 7.9 Hz, 1 H), 6.86 (d, *J* = 5.1 Hz, 1 H), 6.67 (t, *J* = 7.3 Hz, 1 H), 6.44 (d, *J* = 8.3 Hz, 1 H), 5.96 (s, 1 H), 4.50 (d, *J* = 16.0 Hz, 1 H), 4.32 (d, *J* = 16.0 Hz, 1 H), 2.34 (s, 3 H), 2.26 (s, 3 H), 1.89–1.83 (m, 1 H), 1.00–0.94 (m, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ =170.9 (C), 162.7 (C), 155.4 (CH), 144.9 (C), 138.9 (C), 137.1 (C), 136.5 (C), 134.6 (C), 132.7 (C), 130.5 (CH), 129.2 (2 CH), 129.1 (CH), 128.8 (2 CH), 127.4 (2 CH), 127.1 (2 CH), 122.0 (C), 116.7 (CH), 116.3 (CH),

111.4 (CH), 61.5 (CH), 51.7 (CH_2), 21.1 (2 CH_3), 16.9 (CH), 11.1 (CH_2), 10.6 (CH_2) ppm. HRMS (EI): calcd. for $C_{31}H_{29}N_3$ 443.2361; found 443.2363.

Supporting Information (see footnote on the first page of this article): Selected NMR spectra, computational modeling of the van Halban–White cyclization, including Cartesian coordinates.

Acknowledgments

We gratefully acknowledge financial support from the Ministerio de Ciencia e Innovación (MICINN) (CTQ2007-61048/BQU) and Principado de Asturias (PRINCAST) (IB08-088). M.F.-M. also acknowledges the Ministerio de Educación y Ciencia (MEC) for a grant. We also acknowledge Prof. F.J. Fañanás and Prof. C. Valdés for helpful discussions and assistance in the computational modeling.

[1] a) M. Balasubramanian, J. G. Keay, "Pyridines and Their Benzo Derivatives: Application" in *Comprehensive Heterocyclic Chemistry II* (Eds.: A. P. Katrizky, V. W. Rees, E. F. Scriven), Pergamon, Oxford, **1996**, vol. 5, pp. 245–300; b) J. P. Michael, *Nat. Prod. Rep.* **2003**, *20*, 476–493.

[2] For a review, see: A. R. Katritzky, S. Rachwal, B. Rachwal, *Tetrahedron* **1996**, *52*, 15031–15070.

[3] For recent examples, see: a) K. Makino, O. Hara, Y. Takiguchi, T. Katano, Y. Asakawa, K. Hatanoc, Y. Hamada, *Tetrahedron Lett.* **2003**, *44*, 8925–8929; b) P. D. Pohlhaus, R. K. Bowman, J. S. Johnson, *J. Am. Chem. Soc.* **2004**, *126*, 2294–2295; c) C. S. Yi, S. Y. Yun, *J. Am. Chem. Soc.* **2005**, *127*, 17000–17006; d) X.-Y. Liu, P. Ding, J.-S. Huang, C.-M. Che, *Org. Lett.* **2007**, *9*, 2645–2648; e) S.-L. Cui, J. Wang, Y.-G. Wang, *Tetrahedron* **2008**, *64*, 487–492.

[4] Preliminary communication: J. Barluenga, M. Fañanás-Mastral, F. Aznar, C. Valdés, *Angew. Chem.* **2008**, *120*, 6696–6699; *Angew. Chem. Int. Ed.* **2008**, *47*, 6594–6597.

[5] For recent reviews, see: a) J. Barluenga, M. Tomás, J. Santamaría, *Chem. Rev.* **2004**, *104*, 2259–2283; b) K. H. Dötz (Ed.), *Topics in Organometallic Chemistry Vol. 13: Metal Carbenes in Organic Synthesis*, Springer, Berlin, **2004**; c) J. Barluenga, M. A. Fernández-Rodriguez, E. Aguilar, *J. Organomet. Chem.* **2005**, *690*, 539–587; d) Y.-T. Wu, T. Kurahashi, A. de Meijere, *J. Organomet. Chem.* **2005**, *690*, 5900–5911; e) J. W. Herndon, *Coord. Chem. Rev.* **2006**, *250*, 1889–1964.

[6] CCDC-784348 (for **6d**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

[7] For examples of van Halban–White cyclizations on alkenyl Fischer carbene complexes, see: a) T. A. Brandvold, W. D. Wulff, A. L. Rheingold, *J. Am. Chem. Soc.* **1990**, *112*, 1645–1647; b) M. L. Waters, T. A. Brandvold, L. Isaacs, W. D. Wulff, *Organometallics* **1998**, *17*, 4298–4308.

[8] For a similar reaction using alkyl Fischer carbene complexes, see: A. Yamashita, T. A. Scahill, *Tetrahedron Lett.* **1982**, *23*, 3765–3768.

[9] a) W. D. Wulff, W. E. Bauta, R. W. Kaesler, P. J. Lankford, R. A. Miller, C. K. Murray, D. C. Yang, *J. Am. Chem. Soc.* **1990**, *112*, 3642–3659; b) M. Hoffmann, M. Buchert, H. U. Reissig, *Chem. Eur. J.* **1999**, *5*, 876–882; c) J. Barluenga, F. Aznar, A. Martín, *Organometallics* **1995**, *14*, 1429–1433; d) J. Barluenga, F. Aznar, A. Martín, J. Vázquez, *J. Am. Chem. Soc.* **1995**, *117*, 9419–9426.

[10] For some examples, see: a) W. D. Wulff, D. C. Yang, *J. Am. Chem. Soc.* **1984**, *106*, 7565–7567; b) J. Barluenga, F. Aznar, S. Barluenga, *J. Chem. Soc., Chem. Commun.* **1995**, 1973–1974; c) J. Barluenga, M. Fañanás-Mastral, F. Andina, F. Aznar, C. Valdés, *Organometallics* **2008**, *27*, 3593–3600; d) J. Barluenga, M. Fañanás-Mastral, F. Aznar, *Chem. Eur. J.* **2008**, *14*, 7508–7512.

[11] W. D. Wulff, D. C. Yang, C. K. Murray, *J. Am. Chem. Soc.* **1988**, *110*, 2653–2655.

[12] J. Barluenga, M. Tomás, A. Ballesteros, J. Santamaría, R. Corzo-Suárez, S. García-Granda, *New J. Chem.* **2001**, *25*, 8–10.

[13] For recent reviews on the synthesis of pyrimidines, see: a) G. W. Rewcastlea, W. A. Dennya, H. D. H. Showalter, *Curr. Org. Chem.* **2000**, *4*, 679–706; b) M. D. Hill, M. Movassaghi, *Chem. Eur. J.* **2008**, *14*, 6836–6844.

[14] a) J. Barluenga, M. Tomás, A. Ballesteros, J. Santamaría, F. López-Ortiz, *J. Chem. Soc., Chem. Commun.* **1994**, 321–322; b) J. Barluenga, M. Tomás, A. Ballesteros, J. Santamaría, R. J. Carbajo, F. López-Ortiz, S. García-Granda, P. Pertierra, *Chem. Eur. J.* **1996**, *2*, 88–97.

[15] For a similar procedure for the synthesis of dihydropyrimidines, see ref.[5a]

Received: December 22, 2010
Published Online: February 22, 2011

