



HAL
open science

Aminations and arylations by direct C–O activation for the design of 7,8-dihydro-6H -5,8-ethanopyrido[3,2-d]pyrimidines

Mazarine Laurent, Stéphane Bostyn, Mathieu Marchivie, Yves Robin, Sylvain Routier, Frédéric Buron

► To cite this version:

Mazarine Laurent, Stéphane Bostyn, Mathieu Marchivie, Yves Robin, Sylvain Routier, et al.. Aminations and arylations by direct C–O activation for the design of 7,8-dihydro-6H -5,8-ethanopyrido[3,2-d]pyrimidines. RSC Advances, 2021, 11 (32), pp.19363-19377. 10.1039/D1RA03092B . hal-03274724

HAL Id: hal-03274724

<https://hal.science/hal-03274724>



Submitted on 30 Jun 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.


 Cite this: *RSC Adv.*, 2021, 11, 19363

Aminations and arylations by direct C–O activation for the design of 7,8-dihydro-6*H*-5,8-ethanopyrido[3,2-*d*]pyrimidines†

 Mazarine Laurent,^a Stéphane Bostyn,^b Mathieu Marchivie,^c Yves Robin,^d Sylvain Routier ^{*a} and Frédéric Buron ^{*a}

The design of some novel disubstituted 7,8-dihydro-6*H*-5,8-ethanopyrido[3,2-*d*]pyrimidine derivatives is reported. The series was developed from quinuclidinone, which afforded versatile platforms bearing one lactam function in position C-2 that were then used to create C–N or C–C bonds for S_NAr or palladium-catalyzed cross-coupling reactions by *in situ* C–O activation. The reaction conditions were optimized under microwave irradiation, and a wide range of amines or boronic acids were used to determine the scope and limitations of each method. To complete this study, the X-ray crystallographic data of 7,8-dihydro-6*H*-5,8-ethanopyrido[3,2-*d*]pyrimidine derivative **49** were used to formally establish the structures of the products.

 Received 20th April 2021
 Accepted 17th May 2021

DOI: 10.1039/d1ra03092b

rsc.li/rsc-advances

Introduction

Exploring chemical space is a major challenge to discover new biologically active small molecules.^{1–3} This strategy has long been applied in heterocyclic chemistry, in particular through the design and the functionalization of fused polynitrogenated derivatives, which contain hetero-aromatic and aliphatic moieties.^{4–8} The resulting original structures increase the molecular diversity and find applications in reagents, 3D fine chemical or novel pharmaceutical specialities.^{9–11} Among those reported in the aliphatic series, quinuclidine holds an important place due to its presence in a number of natural products, such as *Cinchona officinalis* alkaloids or FDA-approved drugs (Fig. 1).^{12–17} Moreover, this skeleton has also been used as a catalyst for the development of asymmetric aldolisation, Baylis–Hillman or Diels–Alder reactions.^{18–23}

The fusion of quinuclidine to aromatic and nitrogen-containing heterocycle moieties has seldom been reported. Only a few references describe the synthesis and the reactivity of this skeleton with a pyridine group as an example.^{24–26} This may be due to the strong Brønsted and Lewis basic character of the nitrogen atom, which is likely to inhibit a large panel of

reactions.²⁷ For our own part, our group has developed efficient methodologies to functionalize and obtain biologically active molecules in the pyrimidine series such as pyrido[3-2,*d*]pyrimidines, pyrido[1',2':1,5]pyrazolo[3,4-*d*]pyrimidines or pyrido[1',2':1,5]pyrazolo[4,3-*d*]pyrimidine.^{28–31} To escape from flatland and evaluate the replicability of our know-how in this poorly explored area, we propose in this paper the access to a 4-aryl-7,8-dihydro-1*H*-5,8-ethanopyrido[3,2-*d*]pyrimidin-2(6*H*)-one platform and its further substitution at the C-2 position.³² This fused arylated skeleton **A** resulting from the fusion of a quinuclidine and a pyrimidine (quinuclidino-pyrimidinone) was functionalized by aminations or the Suzuki–Miyaura cross-coupling reaction using *in situ* C–O activation, an innovative and direct method that is particularly powerful to modulate heteroaromatic structures (Fig. 2).

Results and discussion

To perform the required C-2 amination or Suzuki–Miyaura cross-coupling reactions, some ethanopyrido[3,2-*d*]pyrimidinones of type **A** were prepared in two steps. First, 4-aryl-

^aInstitut de Chimie Organique et Analytique, ICOA, UMR CNRS 7311, Université d'Orléans, Orléans, France. E-mail: frederic.buron@univ-orleans.fr; sylvain.routier@univ-orleans.fr

^bInstitut de Combustion, Aérothermique, Réactivité, et Environnement (ICARE), 1c, Avenue de la Recherche Scientifique, 45071 CEDEX 2 Orléans, France

^cICMCB CNRS-UMR 5026, Université de Bordeaux, Bordeaux, France

^dISOCEM, 4 Rue Marc Sangnier, 45300 Pithiviers, BP 16729, France

† Electronic supplementary information (ESI) available. CCDC 2074887. For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/d1ra03092b

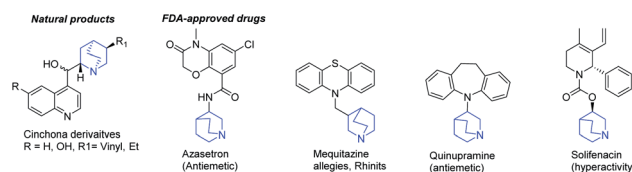


Fig. 1 Some examples of the compounds of interest with a quinuclidine moiety.



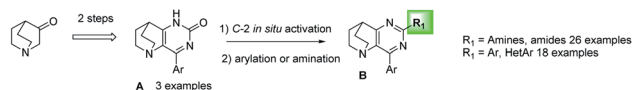
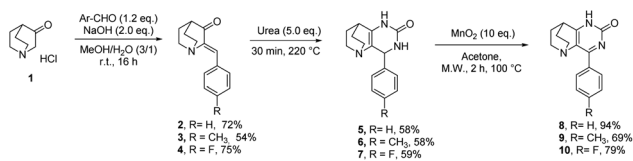


Fig. 2 General scheme leading to 2,4-disubstituted quinuclidino pyrimidines under C–O direct activation.



Scheme 1 Synthesis of 8–10.

7,8-dihydro-1*H*-5,8-ethanopyrido[3,2-*d*]pyrimidin-2(6*H*)one 2–4 were obtained in satisfactory yields after aldol condensation between the commercially available 3-quinuclidinone hydrochloride **1** with three benzaldehydes in presence of sodium hydroxide. Next, a solvent-free condensation with urea was performed to generate bicyclic tetrahydropyrimidines 5–7.³³ Finally, an oxidative hetero aromatization was carried out using manganese dioxide³⁴ in acetone under microwave irradiation to access the desired platforms 8–10 in very good to excellent yields (Scheme 1).

To take advantage of the lactam, we began our methodological study by a one-pot amination at the *C*-2 position using C–O direct activation involving PyBrOP and Et₃N.^{35–37} In this tandem reaction, the first *in situ* step generated the *O*-phosphonium leaving group, which was then displaced with the adequate nucleophile. In a first attempt, the reactivity was examined by treating 4-phenyl-pyrido[3,2-*d*]pyrimidinone **8** with *n*-propylamine and several reaction parameters (temperature, duration) were screened to reach an acceptable level of reaction efficiency (Table 1).^{38,39}

The first step was also performed with **8** in the presence of PyBrOP at a temperature of 80 °C and after 2 h the primary

amine (2.2 eq.) was added. After 3 additional hours, only a small proportion of the intermediate had been consumed and the desired product **11** was isolated in low yield whereas a large amount of starting material **8** was recovered. Increasing the temperature to 100 °C slightly enhanced the yield to 32%. A time reaction screening for each step (*t*₁ and *t*₂) led to interesting results. A full conversion of **8** to *O*-phosphonium was reached after 3 h at 100 °C. The nucleophilic attack of the amine on the activated heterocycle was the rate-limiting step. The second step was achieved during 17 h at 100 °C and led to the desired compound **11** in 72% of yield.

In order to explore the scope and limitations of this tandem sequence, we then condensed previously synthesized ethanopyrido[3,2-*d*]pyrimidinones **A** with various amines (Table 2). With 1-pentylamine and **8**, the yield decreased slightly (entry 2 *versus* 1). The same behaviour was observed when benzyl amines were used (entries 8–10). An attempted strengthening of nucleophilicity with secondary cyclic amines such as piperidine, morpholine or thiomorpholine increased the reactivity up to 82% (entries 3–7). Moreover, when piperidine was used as a secondary amine with ethanopyrido[3,2-*d*]pyrimidinones **9** and **10**, the two S_NAr reactions were efficiently achieved and compounds **23** and **24** were isolated in 86% and 79% of yield, respectively (entries 15–16).

During this investigation, we encountered two limitations when anilines or lactams, which are very weakly nucleophilic species, were used: the final compounds **21** and **22** (entries 12, 13) were never observed. To access these derivatives, it became necessary to develop a one-pot sequence involving *in situ* CO-activation followed by a Pd-catalyzed C–N bond forming sequence, an original alternative to the previously unsuccessful S_NAr method.

Table 2 Synthesis of 11–24

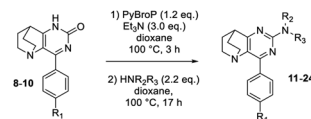


Table 1 Optimization of amination conditions with **8**

Entry	Temp. (°C)	<i>t</i> ₁	<i>t</i> ₂	Yield ^a (%)
1	80	2 h	3 h	23
2	100	2 h	3 h	32
3	100	3 h	3 h	48
4	100	4 h	3 h	47
5	100	3 h	6 h	58
6	100	3 h	17 h	72

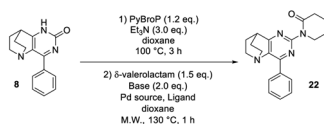
^a Yield is indicated as isolated product.

Entry	R ₁	HNR ₂ R ₃	Cpd, yield ^a
1	H	Propylamine	11 , 72%
2	H	Pentylamine	12 , 59%
3	H	Piperidine	13 , 77%
4	H	Morpholine	14 , 82%
5	H	Thiomorpholine	15 , 72%
7	H	4,4-Difluoropiperidine	16 , 61%
8	H	C ₆ H ₅ CH ₂ NH ₂	17 , 51%
9	H	4-CH ₃ O-C ₆ H ₄ CH ₂ NH ₂	18 , 42%
10	H	4-CF ₃ -C ₆ H ₄ CH ₂ NH ₂	19 , 39%
11	H	Imidazole	20 , 22%
12	H	4-CH ₃ -C ₆ H ₄ NH ₂	21 , ND ^b
13	H	δ-Valerolactam	22 , ND ^b
15	Me	Piperidine	23 , 86%
16	F	Piperidine	24 , 79%

^a Cpd: compound number; yield is indicated as isolated product. ^b Not detected.



Table 3 Optimization of the conditions for the formation of 22



Entry	Catalyst (mol%)	Ligand (mol%)	Base	Temp. (°C)	Yield ^a (%)
1	Pd ₂ dba ₃ (5%)	Xantphos (10%)	K ₂ CO ₃	130	19
2	Pd(OAc) ₂ (5%)	Xantphos (10%)	K ₂ CO ₃	130	21
3	Pd(OAc) ₂ (10%)	Xantphos (20%)	K ₂ CO ₃	130	40
4	Pd(OAc) ₂ (10%)	Xantphos (20%)	K ₂ CO ₃	150	33
5	Pd(OAc) ₂ (10%)	CyJohnPhos (20%)	K ₂ CO ₃	130	0
6	Pd(OAc) ₂ (10%)	RuPhos (20%)	K ₂ CO ₃	130	0
7	Pd(OAc) ₂ (10%)	Xantphos (20%)	Na ₂ CO ₃	130	Traces
8	Pd(OAc) ₂ (10%)	Xantphos (20%)	Cs ₂ CO ₃	130	9

^a Yield is indicated as isolated product.

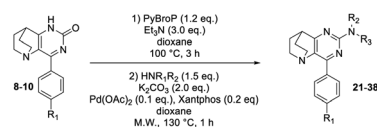
First, we used δ -valerolactam as amide to prevent any S_NAr competition, Pd₂dba₃ as the palladium source in the presence of Xantphos as bidentate ligand, K₂CO₃ as base, and dioxane as solvent. With these conditions, the desired product 22 was isolated in low yield (19%, Table 3, entry 1) despite the total consumption of the starting material, indicating the low reactivity of the *O*-phosphonium intermediate. When the palladium catalyst was replaced by Pd(OAc)₂, the same behaviour was observed and the desired compound 22 was obtained in a similar 21% yield. By increasing the catalytic charge to 10 mol% the *O*-phosphonium species was consumed, affording 22 in 40% of yield accompanied with degradation. A fine adjustment of the temperature (to 150 °C) drastically decreased the yield (entry 4) and the replacement of Xantphos with well-known Buchwald ligands such as CyJohnPhos or Ruphos totally inhibited the reactivity. Changing the nature of the base indicated that the use of Na₂CO₃ and Cs₂CO₃ was not tolerated and showed the highest reaction sensitivity (entries 7, 8).

Next, the scope and generality of the Pd-coupling step were examined. The 2-pyrrolidinone reaction gave the desired product 25 with the same reactivity (Table 4, entry 2), whereas using aniline afforded product 26 in a good isolated yield of 56% (Table 4, entry 4). The reactions proceeded with the same efficiency regardless of the nature of the aniline used (*i.e.*, with electron-withdrawing or electron-donating substituents) and the compound 21 was finally synthesized with these conditions (entry 1). Steric hindrance symbolized by the presence of a methyl group on the aniline in *ortho* vs. *meta* or *para* position (entries 1, 6–7) induced a dramatic decrease in yield. With aminopyridines, reactivity was maintained and compounds 33 and 34 were isolated in 34% and 28% of yield, respectively. The sole limitation in this trend involved the use of 4-(4-fluorophenyl)-7,8-dihydro-1*H*-5,8-ethanopyrido[3,2-*d*]pyrimidinone 10 as starting material, which inhibited the reactivity whereas the tolyl derivative 9 restored the efficiency.

We next focused our attention on using this C–O activation strategy to create a C–C bond instead of a C–N bond under

palladium catalysis.^{28,40,41} In this tandem procedure, the PyBrop activation was achieved as previously described during 3 h and the reagents necessary to perform the cross coupling reaction were then added. Each parameter of the Suzuki–Miyaura reaction was modulated and the results are summarized in Table 5. 24 h of reaction with Pd(OAc)₂ at 110 °C in the presence of a bidentate phosphine proved to be a better catalytic system than with PdCl₂(dppf)·CH₂Cl₂ or Pd(PPh₃)₄ (entries 1–3). Modulation of the base indicated an increase in the yield using K₃PO₄ instead of classical carbonates (entries 3–6) whereas optimization of the nature of the ligand clearly indicated that Xantphos and Ruphos

Table 4 Synthesis of 21–38

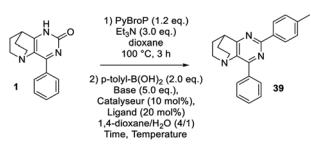


Entry	R ₁	HNR ₂ R ₃	Cpd, yield ^a
1	H	4-CH ₃ -C ₆ H ₄ NH ₂	21, 48%
2	H	δ -Valerolactam	22, 40%
3	H	2-Pyrrolidinone	25, 39%
4	H	C ₆ H ₅ NH ₂	26, 56%
5	H	4-CH ₃ O-C ₆ H ₄ NH ₂	27, 48%
6	H	3-CH ₃ -C ₆ H ₄ NH ₂	28, 31%
7	H	2-CH ₃ -C ₆ H ₄ NH ₂	29, 15%
8	H	4-CF ₃ -C ₆ H ₄ NH ₂	30, 56%
9	H	4-CN-C ₆ H ₄ NH ₂	31, 35%
10	H	4-NO ₂ -C ₆ H ₄ NH ₂	32, 39%
11	H	3-NH ₂ -pyridine	33, 34%
12	H	5-NH ₂ -2-MeOpyridine	34, 28%
13	Me	C ₆ H ₅ NH ₂	35, 44%
14	Me	4-CF ₃ -C ₆ H ₄ NH ₂	36, 49%
15	F	C ₆ H ₅ NH ₂	37, traces
16	F	4-CF ₃ -C ₆ H ₄ NH ₂	38, ND ^b

^a Cpd: compound number; yield is indicated as isolated product. ^b Not detected.



Table 5 Optimization of the conditions for the formation of 39



Entry	Catalyst/ligand	Base	Time step 2	Temp step 2	Yield ^a (%)
1	PdCl ₂ (dppf)·CH ₂ Cl ₂	Na ₂ CO ₃	24 h	110 °C	50
2	Pd(PPh ₃) ₄	Na ₂ CO ₃	24 h	110 °C	41
3	Pd(OAc) ₂ /Xantphos	Na ₂ CO ₃	24 h	110 °C	60
4	Pd(OAc) ₂ /Xantphos	CS ₂ CO ₃	24 h	110 °C	50
5	Pd(OAc) ₂ /Xantphos	K ₂ CO ₃	24 h	110 °C	54
6	Pd(OAc) ₂ /Xantphos	K ₃ PO ₄	24 h	110 °C	68
7	Pd(OAc) ₂ /Xphos	K ₃ PO ₄	24 h	110 °C	62
8	Pd(OAc) ₂ /Ruphos	K ₃ PO ₄	24 h	110 °C	68
9	Pd(OAc) ₂ /Ruphos	K ₃ PO ₄	1 h	150 °C	70

^a Yield is indicated as isolated product.

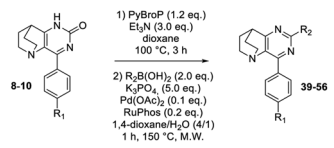
gave the desired compound 39 in the best 68% yield under thermal conditions (entries 6–8). Finally, optimization under microwave irradiation (not shown) established that in the presence of Ruphos at 150 °C the reaction was achieved in only 1 h to furnish 39 in a 70% yield (entry 9).

In the last stage of this study, we investigated the modulation of the nature of the boron derivative to identify the potential

limitations. In fact, whatever the substituent on the phenyl boronic acid (*i.e.*, electron-donating or withdrawing), or the steric hindrance induced by an *ortho* substitution, the C–C bond was efficiently generated and products were isolated in fairly good yields ranging from 54% to 82% (Table 6, products 39–50). The only identified limit concerned the presence of an acidic proton which slightly altered the yield of the reaction but this constraint was easily removed by the use of a protective group such as THP (entries 6–7). The use of (Het)arylboronic acids such as thiophene or pyridine was well tolerated and compounds 51 and 52 were isolated in 77 and 60% of yield, respectively. Finally, proportionally, the reactions conducted with substituted ethanopyrido[3,2-*d*]pyrimidinones 9–10 (entries 15–18) were less efficient than those conducted with 8 (entries 1 vs. 15 or 17, 10 vs. 16 or 18).

During our investigation, we were able to obtain single crystals of 49 suitable for X-ray diffraction analysis (Fig. 3). Compound 49 crystallizes in the monoclinic *P*₂₁ space group with the following cell parameters: *a* = 15.385(8), *b* = 5.893(3), *c*

Table 6 Synthesis of 39–56



Entry	R ₁	R ₂ B(OH) ₂	Cpd, yield ^a
1	H	4-CH ₃ -C ₆ H ₄ B(OH) ₂	39, 70%
2	H	C ₆ H ₅ B(OH) ₂	40, 68%
3	H	3-CH ₃ -C ₆ H ₄ B(OH) ₂	41, 73%
4	H	2-CH ₃ -C ₆ H ₄ B(OH) ₂	42, 76%
5	H	4-CH ₃ O-C ₆ H ₄ B(OH) ₂	43, 69%
6	H	4-OH-C ₆ H ₄ B(OH) ₂	44, 54%
7	H	4-OTHP-C ₆ H ₄ B(OH) ₂	45, 69%
8	H	2-NaphtylB(OH) ₂	46, 67%
9	H	4-F-C ₆ H ₄ B(OH) ₂	47, 70%
10	H	4-CN-C ₆ H ₄ B(OH) ₂	48, 82%
11	H	4-CF ₃ -C ₆ H ₄ B(OH) ₂	49, 72%
12	H	4-NO ₂ -C ₆ H ₄ B(OH) ₂	50, 76%
13	H	3-ThienylB(OH) ₂	51, 77%
14	H	3-PyridylB(OH) ₂	52, 60%
15	Me	4-CH ₃ -C ₆ H ₄ B(OH) ₂	53, 37%
16	Me	4-CN-C ₆ H ₄ B(OH) ₂	54, 52%
17	F	4-CH ₃ -C ₆ H ₄ B(OH) ₂	55, 45%
18	F	4-CN-C ₆ H ₄ B(OH) ₂	56, 68%

^a Cpd: compound number; yield is indicated as isolated product.

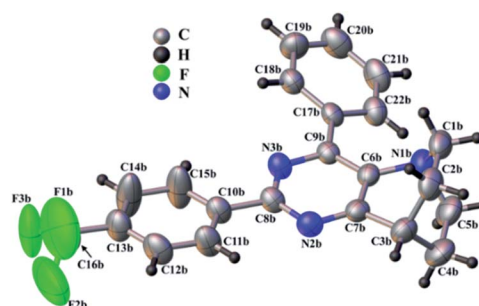


Fig. 3 View of the molecular structure of 49. Only one of the two independent molecules of the asymmetric unit is shown (molecule B). The disorder on the CF₃ moiety is not represented for clarity. The labelling scheme of molecule A is the same but the suffix "b" has been replaced by suffix "a". The thermal atomic displacements are represented using ellipsoids at a 50% probability level.



$= 22.187(14) \text{ \AA}$, $\beta = 110.05(4)^\circ$ and $V = 1890(3) \text{ \AA}^3$. The asymmetric unit is composed of two independent molecules leading to four molecules in the unit cell.

Typical bond lengths are close to the expected values, ranging from 1.352(8) to 1.390(7) \AA for the C–C bonds and from 1.332(6) to 1.356(5) for N–C bonds within the aromatic rings, from 1.477(9) to 1.541(8) \AA , 1.430(6) to 1.488(7) and 1.309(9) to 1.336(10) for single C–C, C–N and C–F bonds respectively.

The pyrimidine and trifluoro-methyl-phenyl rings are almost coplanar with an angle between planes of 7.3(2) and 7.4(2) $^\circ$ for the two independent molecules. Nevertheless, this angle may be underestimated as the trifluoro-methyl-phenyl ring appears slightly disordered. The second phenyl ring, meanwhile, is significantly tilted from the pyrimidine ring plane (25.4(2) $^\circ$ and 26.9(2) $^\circ$) for both molecules. Fig. 3 shows one of the two independent molecules of **49** extracted from the crystal structure. The two molecules are very similar (RMSD = 0.452 \AA) except as regards the phenyl ring, which is reversely tilted in the two molecules.

Conclusions

In summary, the quick access to variously functionalized ethanopyrido[3,2-*d*]pyrimidines has been described herein. Aminated or arylated groups were introduced at the C-2 position of the ethanopyrido[3,2-*d*]pyrimidinones series using a tandem one-pot direct C–O activation sequence involving first PyBroP as activator and next a S_NAr or a palladium cross coupling reaction. Aminations were achieved under S_NAr reactions which were performed with a large variety of amines or using Buchwald–Hartwig cross-coupling reactions in combination with microwave irradiation. In addition, we have also reported the efficiency of the Suzuki–Miyaura reactions in C-2 position, which is compatible with all the boronylated starting material used. This work afforded a novel class of 1,4 disubstituted 7,8-dihydro-6*H*-5,8-ethanopyrido[3,2-*d*]pyrimidines which will undoubtedly have a major impact on the synthesis of new bioactive compounds that contain the rare ethanopyrido[3,2-*d*]pyrimidine scaffold as the central skeleton. Efforts to achieve these objectives are currently in progress.

Experimental section

Materials and methods

^1H NMR and ^{13}C NMR spectra were recorded on a Bruker DPX 250 or 400 Mhz instrument using CDCl_3 and $\text{DMSO-}d_6$. The chemical shifts are reported in parts per million (δ scale), and all coupling constant (J) values are reported in hertz. The following abbreviations were used for the multiplicities: s (singlet), d (doublet), t (triplet), q (quartet), p (pentuplet), m (multiplet), sext (sextuplet), and dd (doublet of doublets). Melting points are uncorrected. IR absorption spectra were obtained on a PerkinElmer PARAGON 1000 PC, and the values are reported in inverse centimeters. HRMS spectra were acquired in positive mode with an ESI source on a Q-TOF mass by the “Fédération de Recherche” ICOA/CBM (FR2708) platform. Monitoring of the reactions was performed using silica gel TLC plates (silica Merck 60 F 254). Spots were visualized by

UV light (254 nm and 356 nm). Column chromatography was performed using silica gel 60 (0.063–0.200 mm, Merck.). Microwave irradiation was carried out in sealed vessels placed in a Biotage Initiator or Biotage Initiator+ system (400 W maximum power). The temperatures were measured externally by IR. Pressure was measured by a non-invasive sensor integrated into the cavity lid. All reagents were purchased from commercial suppliers and were used without further purification. The crystal structure of **49** was solved by single crystal X-ray diffraction at room temperature using a Bruker Apex-II diffractometer with Mo- $K\alpha$ radiation. CCDC 2074887 contains the supplementary crystallographic data for this paper.

Synthetic procedures

General procedure A: aldol condensation. To a solution of 3-quinuclidinone hydrochloride (1.0 eq.) and sodium hydroxide (2.0 eq.) in a mixture of methanol/water (3/1) was added the corresponding aldehyde (1.2 eq.). After stirring at room temperature for 16 h, the reaction mixture was concentrated under reduced pressure to evaporate the methanol. The obtained suspension was filtered, washed with water and dried under vacuum to afford the expected product as a solid.

(Z)-2-Benzylidenequinuclidin-3-one (**2**). The reaction was carried out as described in general procedure A using a solution of 3-quinuclidinone hydrochloride (3.99 g, 24.73 mmol, 1.0 eq.) and sodium hydroxide (1.99 g, 49.7 mmol, 2.0 eq.) in a mixture of methanol/water (3/1, 75 mL) and benzaldehyde (3.0 mL, 29.5 mmol, 1.2 eq.). The reaction mixture was stirred 16 h at r.t. to afford **2** (3.82 g, 72%) as a yellow solid. Rf (PE/EA: 90/10): 0.32. M_p : 141–143 $^\circ\text{C}$. IR (ATR diamond, cm^{-1}): 2941, 2873, 1700, 1621, 1096, 688. ^1H NMR (400 MHz, CDCl_3) δ : 2.03 (td, $J = 3.1, 7.9$ Hz, 4H, 2x CH_2), 2.63 (p, $J = 3.0$ Hz, 1H, CH), 3.00 (dt, $J = 7.6, 12.5$ Hz, 2H, N– CH_2), 3.16 (dt, $J = 7.8, 13.4$ Hz, 2H, N– CH_2), 7.02 (s, 1H, C=CH), 7.29–7.42 (m, 3H, 3xCHAr), 7.97–8.09 (m, 2H, 2xCHAr). ^{13}C NMR (101 MHz, CDCl_3) δ : 26.3 (2x CH_2), 40.7 (CH), 47.9 (2xN– CH_2), 125.5 (C=CH), 128.8 (2xCHAr), 130.0 (CH_{Ar}), 132.6 (2x CH_{Ar}), 134.4 (C_{Ar}), 145.1 (C=CH), 206.8 (C=O). HRMS (EI/MS): m/z calculated for $\text{C}_{14}\text{H}_{16}\text{NO}$: 214.1225 [$M + \text{H}^+$]; found 214.1226.

(Z)-2-(4-Methylbenzylidene)quinuclidin-3-one (**3**). The reaction was carried out as described in general procedure A using a solution of 3-quinuclidinone hydrochloride (4.00 g, 24.79 mmol, 1.0 eq.) and sodium hydroxide (2.01 g, 50.27 mmol, 2.0 eq.) in a mixture of methanol/water (3/1, 75 mL) and *p*-tolualdehyde (3.5 mL, 29.68 mmol, 1.2 eq.). The reaction mixture was stirred 16 h at r.t. to afford **3** (3.05 g, 54%) as a yellow solid. Rf (EP/EA: 90/10): 0.48. M_p : 128–130 $^\circ\text{C}$. IR (ATR diamond, cm^{-1}): 2938, 1700, 1626, 1507, 1251, 1092, 810, 517. ^1H NMR (400 MHz, CDCl_3) δ : 2.01 (td, $J = 7.9, 2.9$ Hz, 4H, 2x CH_2), 2.36 (s, 3H, CH_3), 2.62 (p, $J = 2.9$ Hz, 1H, CH), 2.91–3.04 (m, 2H, N– CH_2), 3.09–3.22 (m, 2H, N– CH_2), 7.00 (s, 1H, C=CH), 7.17 (d, $J = 7.9$ Hz, 2H, 2x CH_{Ar}), 7.93 (d, $J = 8.0$ Hz, 2H, 2x CH_{Ar}). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.5 (CH_3), 25.9 (2x CH_2), 40.3 (CH), 47.5 (2xN– CH_2), 125.2 (=CH), 129.1 (2x CH_{Ar}), 131.2 (C_q), 132.1 (2x CH_{Ar}), 139.9 (C_q), 144.0 (C_q), 206.4 (C=O). HRMS (EI/MS): m/z calculated for $\text{C}_{15}\text{H}_{18}\text{NO}$: 228.1381; found 228.1383.



(*Z*)-2-(4-Fluorobenzylidene)quinuclidin-3-one (**4**). The reaction was carried out as described in general procedure A using a solution of 3-quinuclidinone hydrochloride (4.00 g, 24.76 mmol, 1.0 eq.) and sodium hydroxide (2.00 g, 50.00 mmol, 2.0 eq.) in a mixture of methanol/water (3/1, 75 mL) and 4-fluorobenzaldehyde (3.2 mL, 29.82 mmol, 1.2 eq.). The reaction mixture was stirred 16 h at r.t. to afford **4** (4.33 g, 75%) as a yellow solid. Rf (PE/EA: 90/10): 0.30. M_p : 131–133 °C. IR (ATR diamond, cm^{-1}): 2943, 1698, 1619, 1595, 1502, 1220, 853. ^1H NMR (400 MHz, CDCl_3) δ : 2.02 (td, $J = 7.9, 3.0$ Hz, 4H, $2\times\text{CH}_2$), 2.63 (p, $J = 3.0$ Hz, 1H, CH), 2.90–3.04 (m, 2H, N- CH_2), 3.07–3.21 (m, 2H, N- CH_2), 6.97 (s, 1H, =CH), 6.99–7.10 (m, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.99–8.10 (m, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 26.0 ($2\times\text{CH}_2$), 40.3 (CH), 47.5 ($2\times\text{N-CH}_2$), 115.5 (d, $J = 21.5$ Hz, $2\times\text{CH}_{\text{Ar}}$), 123.9 (=CH), 130.3 (d, $J = 3.4$ Hz, C=), 134.3 (d, $J = 8.1$ Hz, $2\times\text{CH}_{\text{Ar}}$), 144.3 (d, $J = 2.6$ Hz, C_{Ar}), 163.3 (d, $J = 251.6$ Hz, $\text{C}_{\text{Ar-F}}$), 206.3 (C=O). ^{19}F NMR (376 MHz, CDCl_3) δ : -109.84. HRMS (EI/MS): m/z calculated for $\text{C}_{14}\text{H}_{15}\text{FNO}$: 232.1132 [$\text{M} + \text{H}$] $^+$; found 232.1132.

4-Phenyl-3,4,7,8-tetrahydro-1H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2(6H)-one (**5**). **2** (4.998 g, 23.43 mmol, 1.0 eq.) and urea (7.050 g, 117.38 mmol, 5.0 eq.) were ground in a mortar and put in a 100 mL-flask. The mixture was then heated at 220 °C in a pre-heated bath. After 30 min, 80 mL of a solution of NaOH 2 N were added, and the resulting mixture was allowed to cool to room temperature. The precipitate formed was filtered, washed with water (80 mL), DCM (80 mL) and acetone (2×80 mL) to afford **5** (3.505 g, 58%) as a white solid. Rf (DCM/MeOH: 95/5): 0.44. M_p : >260 °C. IR (ATR diamond, cm^{-1}): 3295, 2951, 1681, 1642, 1454, 1241, 752, 732, 691. ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.30–1.43 (m, 1H, CH), 1.45–1.56 (m, 2H, $2\times\text{CH}$), 1.56–1.65 (m, 1H, CH), 1.65–1.79 (m, 1H, N-CH), 2.50–2.61 (m, 3H, $2\times\text{N-CH}$, CH), 2.76 (ddd, $J = 4.6, 8.6, 12.9$ Hz, 1H, N-CH), 4.83 (d, $J = 2.1$ Hz, 1H, CH), 6.98 (s, 1H, NH), 7.20–7.35 (m, 5H, $5\times\text{CH}_{\text{Ar}}$), 8.35 (s, 1H, NH). ^{13}C NMR (101 MHz, $\text{DMSO-}d_6$) δ : 27.9 (CH), 28.6 (CH_2), 28.7 (CH_2), 49.9 (N- CH_2), 50.0 (N- CH_2), 57.9 (CH), 118.3 (C_{q}), 126.7 ($2\times\text{CH}_{\text{Ar}}$), 127.1 (CH), 128.1 ($2\times\text{CH}_{\text{Ar}}$), 137.2 (C_{q}), 144.4 (C_{q}), 152.5 (C_{q}). HRMS (EI/MS): m/z calculated for $\text{C}_{15}\text{H}_{18}\text{N}_3\text{O}$: 256.1442 [$\text{M} + \text{H}$] $^+$; found: 256.1444.

4-(*p*-Tolyl)-3,4,7,8-tetrahydro-1H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2(6H)-one (**6**). **3** (3.97 g, 17.48 mmol, 1.0 eq.) and urea (5.25 g, 87.51 mmol, 5.0 eq.) were ground in a mortar and put in a 100 mL-flask. The mixture was then heated at 220 °C in a pre-heated bath. After 30 min, 60 mL of a solution of NaOH 2 N were added, and the resulting mixture was allowed to cool to room temperature. The precipitate formed was filtered, washed with water (60 mL), DCM (60 mL) and acetone (2×60 mL) to afford **6** (2.76 g, 58%) as a white solid. Rf (DCM/MeOH: 95/5): 0.22. M_p : >260 °C. IR (ATR diamond, cm^{-1}): 3294, 3091, 2941, 1644, 1455, 1340, 1102, 750. ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.31–1.41 (m, 1H, CH), 1.43–1.56 (m, 2H, $2\times\text{CH}$), 1.56–1.64 (m, 1H, CH), 1.70–1.81 (m, 1H, N-CH), 2.27 (s, 3H, CH_3), 2.52–2.61 (m, 3H, $2\times\text{N-CH}$, CH), 2.69–2.80 (m, 1H, N-CH), 4.78 (s, 1H, NH-CH), 6.91 (s, 1H, NH), 7.13 (dd, $J = 9.0, 10.4$ Hz, 4H, $4\times\text{CH}_{\text{Ar}}$), 8.31 (s, 1H, NH). ^{13}C NMR (101 MHz, $\text{DMSO-}d_6$) δ : 20.6 (CH_3), 27.8 (CH), 28.6 (CH_2), 28.7 (CH_2), 49.8 (N- CH_2), 50.0 (N- CH_2),

57.6 (CH), 118.4 (C_{q}), 126.6 ($2\times\text{CH}_{\text{Ar}}$), 128.6 ($2\times\text{CH}_{\text{Ar}}$), 136.0 (C_{q}), 137.0 (C_{q}), 141.5 (C_{q}), 152.4 (C_{q}). HRMS (EI/MS): m/z calculated for $\text{C}_{16}\text{H}_{20}\text{N}_3\text{O}$: 270.1601 [$\text{M} + \text{H}$] $^+$; found: 270.1596.

4-(4-Fluorophenyl)-3,4,7,8-tetrahydro-1H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2(6H)-one (**7**). **4** (2.0 g, 8. mmol, 1.0 eq.) and urea (2.60 g, 43.42 mmol, 5.0 eq.) were ground in a mortar and put in a 50 mL-flask. The mixture was then heated at 220 °C in a pre-heated bath. After 30 min, 30 mL of a solution of NaOH 2 N were added, and the resulting mixture was allowed to cool to room temperature. The precipitate formed was filtered, washed with water (30 mL), DCM (30 mL) and acetone (2×30 mL) to afford **7** (1.40 g, 59%) as a white solid. Rf (DCM/MeOH: 95/5): 0.19. M_p : 258–260 °C. IR (ATR diamond, cm^{-1}): 3302, 3093, 2945, 1638, 1505, 1221, 1155, 1098, 748. ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.31–1.43 (m, 1H, CH), 1.44–1.53 (m, 2H, $2\times\text{CH}$), 1.53–1.66 (m, 1H, CH), 1.72 (tt, $J = 3.3, 12.8$ Hz, 1H, N-CH), 2.52–2.63 (m, 3H, $2\times\text{N-CH}$, CH), 2.70–2.81 (m, 1H, N-CH), 4.85 (s, 1H, NH-CH), 7.00 (s, 1H, NH), 7.14 (t, $J = 8.7$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.29 (dd, $J = 5.6, 8.4$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.37 (s, 1H, NH). ^{13}C NMR (101 MHz, $\text{DMSO-}d_6$) δ : 27.8 (CH), 28.6 ($2\times\text{CH}_2$), 49.8 (N- CH_2), 50.0 (N- CH_2), 57.1 (CH), 114.6 (CH_{Ar}), 114.8 (CH_{Ar}), 118.1 (C_{q}), 128.5 (CH_{Ar}), 128.6 (CH_{Ar}), 137.3 (C_{q}), 140.6 (d, $J = 2.9$ Hz, C_{q}), 152.3 (C_{q}), 161.3 (d, $J = 242.4$ Hz, $\text{C}_{\text{Ar-F}}$). ^{19}F NMR (376 MHz, $\text{DMSO-}d_6$) δ : -115.92. HRMS (EI/MS): m/z calculated for $\text{C}_{15}\text{H}_{17}\text{FN}_3\text{O}$: 274.1350 [$\text{M} + \text{H}$] $^+$; found: 274.1350.

4-Phenyl-7,8-dihydro-1H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2(6H)-one (**8**). In a microwave vial of 10–20 mL, MnO_2 (873 mg, 10.0 mmol, 10.0 eq.) was added to a solution of **5** (259 mg, 1.0 mmol, 1.0 eq.) in acetone (12 mL). The reaction mixture was heated for 2 h at 100 °C under microwave irradiation. The reaction mixture was filtered through celite and washed with acetone (20 mL), DCM (20 mL) and MeOH (20 mL). The solvents were evaporated to give **8** (237 mg, 94%) as a white solid without further purification. Rf (DCM/MeOH: 95/5): 0.38. M_p : >260 °C. IR (ATR diamond, cm^{-1}): 2967, 2928, 1626, 1551, 1442, 1390, 1324, 1128, 776, 747, 685. ^1H NMR (400 MHz, CDCl_3) δ : 1.74–1.86 (m, 2H, CH_2), 1.94–2.06 (m, 2H, CH_2), 2.72 (td, $J = 4.7, 11.3, 11.7$ Hz, 2H, N- CH_2), 3.08–3.19 (m, 3H, N- CH_2 , CH), 7.44–7.56 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.02 (d, $J = 7.0$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 13.00 (s, 1H, NH). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.0 ($2\times\text{CH}_2$), 33.9 (CH), 49.3 ($2\times\text{N-CH}_2$), 126.1 (C_{q}), 128.6 ($2\times\text{CH}_{\text{Ar}}$), 129.8 ($2\times\text{CH}_{\text{Ar}}$), 131.2 (CH_{Ar}), 158.8 (C_{q}). HRMS (EI/MS): m/z calculated for $\text{C}_{15}\text{H}_{16}\text{N}_3\text{O}$: 254.1286 [$\text{M} + \text{H}$] $^+$; found: 254.1288.

4-(*p*-Tolyl)-7,8-dihydro-1H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2(6H)-one (**9**). In a microwave vial of 10–20 mL, MnO_2 (1.11 g, 12.8 mmol, 10.0 eq.) was added to a solution of **6** (331 mg, 1.2 mmol, 1.0 eq.) in acetone (18 mL). The reaction mixture was heated for 2 h at 100 °C under microwave irradiation. The reaction mixture was filtered through celite and washed with acetone (20 mL), DCM (20 mL) and MeOH (20 mL). The solvents were evaporated to give **9** (225 mg, 69%) as a white solid without further purification. Rf (DCM/MeOH: 95/5): 0.27. M_p : >260 °C. IR (ATR diamond, cm^{-1}): 2963, 2942, 2869, 1710, 1633, 1449, 1357, 803, 746. ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.68–1.80 (m, 2H, CH_2), 2.02–2.13 (m, 2H, CH_2), 2.41 (s, 3H, CH_3), 2.68–2.79 (m, 2H, N- CH_2), 3.10–3.21 (m, 2H, N- CH_2), 3.25 (p, $J = 2.6$ Hz, 1H, CH), 7.40 (d, $J = 8.0$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.72 (d, $J = 8.2$ Hz, 2H,



$2x\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, DMSO- d_6) δ : 21.2 (CH_3), 25.3 ($2x\text{CH}_2$), 30.7 (CH), 48.8 ($2x\text{N-CH}_2$), 115.2 (q, $J = 288.7$ Hz, TFA), 124.0 (C_q), 124.6 (C_q), 129.2 ($2x\text{CH}_{\text{Ar}}$), 130.5 ($2x\text{CH}_{\text{Ar}}$), 143.5 (C_q), 149.5 (C_q), 156.6 (C_q), 158.5 (q, $J = 38.1$ Hz, TFA), 177.9 (C=O). HRMS (EI/MS): m/z calculated for $\text{C}_{16}\text{H}_{18}\text{N}_3\text{O}$: 268.1444 [$\text{M} + \text{H}$] $^+$; found: 268.1448.

4-(4-Fluorophenyl)-7,8-dihydro-1H-5,8-ethanopyrido[3,2-d]pyrimidin-2(6H)-one (10). In a microwave vial of 10–20 mL, MnO_2 (1.30 g, 15.0 mmol, 10.0 eq.) was added to a solution of **7** (413 mg, 1.5 mmol, 1.0 eq.) in acetone (18 mL). The reaction mixture was heated for 2 h at 100 °C under microwave irradiation. The reaction mixture was filtered through celite and washed with acetone (20 mL), DCM (20 mL) and MeOH (20 mL). The solvents were evaporated to give **10** (321 mg, 79%) as a white solid without further purification. Rf (DCM/MeOH, 95/5): 0.30. M_p : >260 °C. IR (ATR diamond, cm^{-1}) ν : 2944, 1651, 1590, 1556, 1450, 1359, 1230, 1157, 800, 658. ^1H NMR (400 MHz, DMSO- d_6) δ : 1.68–1.80 (m, 2H, CH_2), 2.02–2.14 (m, 2H, CH_2), 2.70–2.81 (m, 2H, N-CH_2), 3.12–3.22 (m, 2H, N-CH_2), 3.25 (p, $J = 3.0$ Hz, 1H, CH), 7.43 (t, $J = 8.7$ Hz, 2H, $2x\text{CH}_{\text{Ar}}$), 7.88 (dd, $J = 8.7, 5.3$ Hz, 2H, $2x\text{CH}_{\text{Ar}}$), 14.00 (s, TFA). ^{13}C NMR (101 MHz, DMSO- d_6) δ : 25.20 ($2x\text{CH}_2$), 30.84 (CH), 48.92 ($2x\text{N-CH}_2$), 115.34 (q, $J = 290.4$ Hz, TFA), 115.66 (CH_{Ar}), 115.88 (CH_{Ar}), 124.01 (C_q), 124.40 (d, $J = 2.7$ Hz, C_q), 133.24 (CH_{Ar}), 133.33 (CH_{Ar}), 150.35 (C_q), 155.47 (C_q), 158.54 (m, TFA), 164.64 (d, $J = 251.8$ Hz, $\text{C}_{\text{Ar-F}}$), 177.85 (C_q). ^{19}F NMR (376 MHz, CDCl_3) δ : -75.86 (TFA), -100.94. HRMS (EI/MS): m/z calculated for $\text{C}_{15}\text{H}_{15}\text{FN}_3\text{O}$: 272.1194 [$\text{M} + \text{H}$] $^+$; found: 272.1194.

General procedure B: $\text{S}_{\text{N}}\text{Ar}$ via PyBroP activation. In a microwave vial, to a solution of **8** (200 mg, 0.79 mmol, 1.0 eq.) and PyBroP (446 mg, 0.96 mmol, 1.2 eq.) in 1,4-dioxane (8 mL) was added Et_3N (0.32 mL, 2.36 mmol, 3.0 eq.). The mixture was then degassed by argon bubbling for 15 minutes. The sealed tube was heated at 100 °C for 3 h. After cooling, the corresponding amine (2.2 eq.) was added, and the reaction mixture was heated at 100 °C for 17 h. After cooling to room temperature, the solvent was evaporated under reduced atmosphere. The crude material was purified by flash chromatography on silica gel to give the desired compound.

4-Phenyl-N-propyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-amine (11). Compound **11** was obtained according to the general procedure B using propylamine (0.14 mL, 1.73 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 70/30), **11** (167 mg, 72%) was obtained as a white solid. Rf (PE/EA: 70/30): 0.37. M_p : 149–151 °C. IR (ATR diamond, cm^{-1}) ν : 3264, 3115, 2955, 2869, 1596, 1360, 1131, 770, 687, 626. ^1H NMR (400 MHz, CDCl_3) δ : 1.01 (t, $J = 7.4$ Hz, 3H, CH_3), 1.67 (h, $J = 7.0$ Hz, 2H, CH_2), 1.71–1.81 (m, 2H, CH_2), 1.90–2.02 (m, 2H, CH_2), 2.72 (td, $J = 4.7, 11.2$ Hz, 2H, N-CH_2), 3.04 (p, $J = 3.0$ Hz, 1H, CH), 3.104–3.21 (m, 2H, N-CH_2), 3.47 (q, $J = 6.6$ Hz, 2H, CH_2), 5.03 (t, $J = 5.8$ Hz, 1H, NH), 7.36–7.49 (m, 3H, $3x\text{CH}_{\text{Ar}}$), 8.25 (d, $J = 7.2$ Hz, 2H, $2x\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 11.7 (CH_3), 23.1 (CH_2), 27.8 ($2x\text{CH}_2$), 33.7 (CH), 43.7 (CH_2), 49.4 ($2x\text{N-CH}_2$), 128.1 ($2x\text{CH}_{\text{Ar}}$), 129.5 (CH_{Ar}), 129.8 ($2x\text{CH}_{\text{Ar}}$), 131.4 (C_q), 136.7 (C_q), 155.6 (C_q), 160.1 (C_q), 175.6 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{18}\text{H}_{23}\text{N}_4$: 295.1916 [$\text{M} + \text{H}$] $^+$; found: 295.1917.

N-Pentyl-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-amine (12). Compound **12** was obtained according to the general procedure B using amylamine (0.20 mL, 1.71 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 70/30), **12** (150 mg, 59%) was obtained as a white solid. Rf (PE/EA: 70/30): 0.38. M_p : 138–140 °C. IR (ATR diamond, cm^{-1}) ν : 3256, 2947, 2867, 1569, 1359, 1130, 773, 688, 625. ^1H NMR (400 MHz, CDCl_3) δ : 0.92 (t, $J = 6.8$ Hz, 3H, CH_3), 1.31–1.47 (m, 4H, CH_2), 1.66 (q, $J = 7.1$ Hz, 2H, $\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$), 1.69–1.81 (m, 2H, CH_2), 1.90–2.02 (m, 2H, CH_2), 2.72 (td, $J = 5.0, 11.4$ Hz, 2H, N-CH_2), 3.04 (p, $J = 3.1$ Hz, 1H, CH), 3.09–3.21 (m, 2H, N-CH_2), 3.49 (q, $J = 6.6$ Hz, 2H, CH_2), 5.02 (t, $J = 5.7$ Hz, 1H, NH), 7.36–7.49 (m, 3H, $3x\text{CH}_{\text{Ar}}$), 8.25 (d, $J = 7.1$ Hz, 2H, $2x\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 14.2 (CH_3), 22.6 (CH_2), 27.8 ($2x\text{CH}_2$), 29.3 (CH_2), 29.6 (CH_2), 33.7 (CH), 41.9 (CH_2), 49.4 ($2x\text{N-CH}_2$), 128.1 ($2x\text{CH}_{\text{Ar}}$), 129.5 (CH_{Ar}), 129.8 ($2x\text{CH}_{\text{Ar}}$), 131.3 (C_q), 136.7 (C_q), 155.5 (C_q), 160.0 (C_q), 175.6 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{20}\text{H}_{27}\text{N}_4$: 323.2230 [$\text{M} + \text{H}$] $^+$; found: 323.2230.

4-Phenyl-2-(piperidin-1-yl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (13). Compound **13** was obtained according to the general procedure B using piperidine (0.17 mL, 1.71 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **13** (195 mg, 77%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.41. M_p : 207–209 °C. IR (ATR diamond, cm^{-1}) ν : 2939, 2863, 1571, 1503, 1386, 1290, 776, 694, 624. ^1H NMR (400 MHz, CDCl_3) δ : 1.60–1.69 (m, 6H, $3x\text{CH}_2$), 1.70–1.82 (m, 2H, CH_2), 1.89–2.01 (m, 2H, CH_2), 2.71 (td, $J = 4.8, 11.2$ Hz, 2H, N-CH_2), 3.07 (p, $J = 3.1$ Hz, 1H, CH), 3.10–3.21 (m, 2H, N-CH_2), 3.87 (t, $J = 4.9$ Hz, 4H, $2x\text{N-CH}_2$), 7.36–7.48 (m, 3H, $3x\text{CH}_{\text{Ar}}$), 8.25–8.32 (m, 2H, $2x\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 25.1 (CH_2), 26.0 ($2x\text{CH}_2$), 27.7 ($2x\text{CH}_2$), 33.9 (CH), 45.19 ($2x\text{CH}_2$), 49.5 ($2x\text{N-CH}_2$), 128.05 (CH_{Ar}), 129.4 (CH_{Ar}), 129.91 ($2x\text{CH}_{\text{Ar}}$), 130.1 (C_q), 137.1 (C_q), 154.9 (C_q), 159.6 (C_q), 175.2 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{20}\text{H}_{25}\text{N}_4$: 321.2074 [$\text{M} + \text{H}$] $^+$; found: 321.2070.

4-(4-Phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-yl)morpholine (14). Compound **14** was obtained according to the general procedure B using morpholine (0.15 mL, 1.73 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **14** (210 mg, 82%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.20. M_p : 212–214 °C. IR (ATR diamond, cm^{-1}) ν : 2949, 2858, 1552, 1483, 1385, 1263, 1115, 774, 688, 624. ^1H NMR (400 MHz, CDCl_3) δ : 1.69–1.81 (m, 2H, CH_2), 1.91–2.03 (m, 2H, CH_2), 2.72 (td, $J = 4.7, 11.1$ Hz, 2H, N-CH_2), 3.09 (p, $J = 3.1$ Hz, 1H, CH), 3.17 (ddd, $J = 4.8, 9.6, 13.8$ Hz, 2H, N-CH_2), 3.81 (q, $J = 3.9, 4.4$ Hz, 4H, $2x\text{CH}_2\text{-O}$), 3.88 (q, $J = 3.4, 4.0$ Hz, 4H, $2x\text{N-CH}_2$), 7.37–7.49 (m, 3H, $3x\text{CH}_{\text{Ar}}$), 8.26–8.35 (m, 2H, $2x\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.9 ($2x\text{CH}_2$), 33.8 (CH), 44.8 ($2x\text{N-CH}_2$), 49.4 ($2x\text{N-CH}_2$), 67.17 ($2x\text{CH}_2\text{-O}$), 128.1 ($2x\text{CH}_{\text{Ar}}$), 129.7 (CH_{Ar}), 129.92 ($2x\text{CH}_{\text{Ar}}$), 131.5 (C_q), 136.8 (C_q), 155.0 (C_q), 159.5 (C_q), 175.5 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{19}\text{H}_{23}\text{N}_4\text{O}$: 323.1866 [$\text{M} + \text{H}$] $^+$; found: 323.1868.

4-(4-Phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-yl)thiomorpholine (15). Compound **15** was obtained according to the general procedure B using thiomorpholine (0.17 mL,



1.68 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **15** (193 mg, 72%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.36. M_p : 211–213 °C. IR (ATR diamond, cm^{-1}): 2951, 2926, 1555, 1481, 1387, 1258, 771, 696, 624. ^1H NMR (400 MHz, CDCl_3) δ : 1.72–1.83 (m, 2H, CH_2), 1.93–2.05 (m, 2H, CH_2), 2.68–2.80 (m, 6H, $2\times\text{S-CH}_2$, N-CH_2), 3.09 (p, $J = 3.0$ Hz, 1H, CH), 3.13–3.24 (m, 2H, N-CH_2), 4.24–4.30 (m, 4H, $\text{CH}_2\text{-N}$), 7.39–7.51 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.27–8.36 (m, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.2 ($2\times\text{S-CH}_2$), 27.9 ($2\times\text{CH}_2$), 33.8 (CH), 46.6 ($2\times\text{CH}_2\text{-N}$), 49.4 ($2\times\text{N-CH}_2$), 128.0 ($2\times\text{CH}_{\text{Ar}}$), 129.6 (CH_{Ar}), 129.8 ($2\times\text{CH}_{\text{Ar}}$), 130.9 (C_q), 136.8 (C_q), 155.0 (C_q), 158.9 (C_q), 175.56 (C_q). HRMS (EI/MS): m/z calculated $\text{C}_{19}\text{H}_{23}\text{N}_4\text{S}$: 339.1638 [$\text{M} + \text{H}$] $^+$; found: 339.1637.

2-(4,4-Difluoropiperidin-1-yl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (16). Compound **16** was obtained according to the general procedure **B** using 4,4-difluoropiperidine hydrochloride (271 mg, 1.72 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **16** (172 mg, 61%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.32. M_p : 212–214 °C. IR (ATR diamond, cm^{-1}): 2954, 2871, 1568, 1489, 1356, 1108, 1048, 777, 690, 624, 511. ^1H NMR (400 MHz, CDCl_3) δ : 1.61–1.85 (m, 2H, CH_2), 1.83–2.23 (m, 6H, $3\times\text{CH}_2$), 2.72 (td, $J = 5.1, 11.5$ Hz, 2H, N-CH_2), 3.09 (p, $J = 3.1$ Hz, 1H, CH), 3.12–3.23 (m, 2H, N-CH_2), 4.07 (t, $J = 5.8$ Hz, 4H, $2\times\text{N-CH}_2$), 7.27–7.57 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.29 (d, $J = 7.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.8 ($2\times\text{CH}_2$), 33.8 (CH), 34.0 (t, $J = 22.6$ Hz, $2\times\text{CH}_2\text{-CF}_2$), 41.3 (t, $J = 5.2$ Hz, $2\times\text{N-CH}_2$), 49.3 ($2\times\text{N-CH}_2$), 122.8 (t, $J = 241.7$ Hz, CF_2), 128.1 ($2\times\text{CH}_{\text{Ar}}$), 129.7 (CH_{Ar}), 129.9 ($2\times\text{CH}_{\text{Ar}}$), 131.4 (C_q), 136.7 (C_q), 155.1 (C_q), 158.8 (C_q), 175.7 (C_q). ^{19}F NMR (376 MHz, CDCl_3) δ : –96.89. HRMS (EI/MS): m/z calculated $\text{C}_{20}\text{H}_{23}\text{F}_2\text{N}_4$: 357.1885 [$\text{M} + \text{H}$] $^+$; found: 357.1886.

N-Benzyl-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-amine (17)

Compound **17** was obtained according to the general procedure **B** using benzylamine (0.19 mL, 1.73 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 60/40), **17** (141 mg, 51%) was obtained as a white solid. Rf (PE/EA: 70/30): 0.45. M_p : 182–184 °C. IR (ATR diamond, cm^{-1}): 3252, 3084, 2940, 2869, 1570, 1543, 1347, 1133, 774, 689, 626. ^1H NMR (400 MHz, CDCl_3) δ : 1.69–1.82 (m, 2H), 1.92–2.03 (m, 2H), 2.73 (td, $J = 5.1, 11.4$ Hz, 2H), 3.06 (p, $J = 3.1$ Hz, 1H, CH), 3.11–3.22 (m, 2H), 4.73 (d, $J = 5.8$ Hz, 2H, NH-CH_2), 5.35 (t, $J = 5.7$ Hz, 1H, NH), 7.27 (t, $J = 7.3$ Hz, 1H, CH_{Ar}), 7.34 (t, $J = 7.4$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.39–7.48 (m, 5H, $5\times\text{CH}_{\text{Ar}}$), 8.26 (d, $J = 8.1$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 46.0 (NH-CH_2), 49.4 ($2\times\text{N-CH}_2$), 127.2 (CH_{Ar}), 127.8 ($2\times\text{CH}_{\text{Ar}}$), 128.1 ($2\times\text{CH}_{\text{Ar}}$), 128.6 ($2\times\text{CH}_{\text{Ar}}$), 129.6 (CH_{Ar}), 129.9 ($2\times\text{CH}_{\text{Ar}}$), 131.9 (C_q), 136.6 (C_q), 139.9 (C_q), 159.7 (C_q), 175.9 (C_q). HRMS (EI/MS): m/z calculated $\text{C}_{22}\text{H}_{23}\text{N}_4$: 343.1917 [$\text{M} + \text{H}$] $^+$; found: 343.1919.

N-(4-Methoxybenzyl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-amine (18). Compound **18** was obtained according to the general procedure **B** using 4-methoxybenzylamine (0.23 mL, 1.75 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 80/20 to 70/30), **18** (126 mg, 42%) was obtained as a white solid. Rf (PE/EA: 70/30): 0.26. M_p :

204–206 °C. IR (ATR diamond, cm^{-1}): 3252, 2945, 1595, 1569, 1544, 1509, 1242, 1172, 1031, 808, 690. ^1H NMR (400 MHz, CDCl_3) δ : 1.68–1.81 (m, 2H, CH_2), 1.91–2.03 (m, 2H, CH_2), 2.66–2.79 (m, 2H, N-CH_2), 3.06 (p, $J = 2.9$ Hz, 1H, CH), 3.11–3.22 (m, 2H, N-CH_2), 3.80 (s, 3H, OCH_3), 4.65 (d, $J = 5.7$ Hz, 2H, NH-CH_2), 5.32 (t, $J = 5.8$ Hz, 1H, NH-CH_2), 6.88 (dt, $J = 3.0, 8.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.35 (dt, $J = 2.6, 8.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.39–7.48 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.27 (dd, $J = 1.7, 7.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 45.5 (NH-CH_2), 49.4 ($2\times\text{N-CH}_2$), 55.4 (CH_3), 114.0 ($2\times\text{CH}_{\text{Ar}}$), 128.1 ($2\times\text{CH}_{\text{Ar}}$), 129.1 ($2\times\text{CH}_{\text{Ar}}$), 129.6 (CH_{Ar}), 129.9 ($2\times\text{CH}_{\text{Ar}}$), 131.8 (C_q), 131.9 (C_q), 136.6 (C_q), 158.9 (C_q), 159.7 (C_q), 175.8 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{23}\text{H}_{25}\text{N}_4\text{O}$: 373.2023 [$\text{M} + \text{H}$] $^+$; found: 373.2020.

4-Phenyl-N-(4-(trifluoromethyl)benzyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-amine (19). Compound **19** was obtained according to the general procedure **B** using 4-(trifluoromethyl)benzylamine (0.25 mL, 1.75 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 80/20 to 70/30), **19** (129 mg, 39%) was obtained as a white solid. Rf (PE/EA: 70/30): 0.25. M_p : 180–182 °C. IR (ATR diamond, cm^{-1}): 3255, 2948, 1566, 1326, 1112, 1061, 691. ^1H NMR (400 MHz, CDCl_3) δ : 1.67–1.81 (m, 2H, CH_2), 1.92–2.04 (m, 2H, CH_2), 2.66–2.79 (m, 2H, N-CH_2), 3.05 (p, $J = 3.0$ Hz, 1H, CH), 3.11–3.22 (m, 2H, N-CH_2), 4.79 (d, $J = 6.1$ Hz, 2H, NH-CH_2), 5.52 (t, $J = 6.1$ Hz, 1H, NH), 7.37–7.47 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 7.53 (d, $J = 8.1$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.59 (d, $J = 8.2$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.19–8.26 (m, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 45.5 (NH-CH_2), 49.3 ($2\times\text{N-CH}_2$), 124.3 (d, $J = 271.9$ Hz, $\text{C}_q\text{-CF}_3$), 125.5 (q, $J = 3.7$ Hz, $2\times\text{CH}_{\text{Ar}}$), 127.8 ($2\times\text{CH}_{\text{Ar}}$), 128.1 ($2\times\text{CH}_{\text{Ar}}$), 129.4 (d, $J = 32.2$ Hz, CF_3), 129.7 (CH_{Ar}), 129.8 ($2\times\text{CH}_{\text{Ar}}$), 132.2 (C_q), 136.4 (C_q), 144.3 (C_q), 155.5 (C_q), 159.5 (C_q), 176.1 (C_q). ^{19}F NMR (376 MHz, CDCl_3) δ : –62.37. HRMS (EI/MS): m/z calculated for $\text{C}_{23}\text{H}_{22}\text{F}_3\text{N}_4$: 411.1791 [$\text{M} + \text{H}$] $^+$; found: 411.1792.

2-(1H-Imidazol-1-yl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (20). Compound **20** was obtained according to the general procedure **B** using imidazole (123 mg, 1.80 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 70/30), **20** (55 mg, 22%) was obtained as a white solid. Rf (PE/EA: 70/30): 0.10. M_p : 198–200 °C. IR (ATR diamond, cm^{-1}): 2963, 2926, 2868, 1561, 1468, 1435, 1387, 1050, 691. ^1H NMR (400 MHz, CDCl_3) δ : 1.73–1.85 (m, 2H, CH_2), 2.02–2.15 (m, 2H, CH_2), 2.75 (td, $J = 5.1, 11.6$ Hz, 2H, N-CH_2), 3.21–3.32 (m, 2H, N-CH_2), 3.34 (p, $J = 3.1$ Hz, 1H, CH), 7.18 (s, 1H, $\text{CH}_{\text{imidazole}}$), 7.51 (dd, $J = 2.5, 4.5$ Hz, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.00 (s, 1H, $\text{CH}_{\text{imidazole}}$), 8.41–8.49 (m, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.70 (s, 1H, $\text{CH}_{\text{imidazole}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.7 ($2\times\text{CH}_2$), 33.6 (CH), 48.8 ($2\times\text{N-CH}_2$), 116.9 ($\text{CH}_{\text{imidazole}}$), 128.4 ($2\times\text{CH}_{\text{Ar}}$), 130.2 ($2\times\text{CH}_{\text{Ar}}$), 130.4 ($\text{CH}_{\text{imidazole}}$), 130.8 (CH_{Ar}), 135.0 (C_q), 136.4 ($\text{CH}_{\text{imidazole}}$), 138.9 (C_q), 151.3 (C_q), 156.2 (C_q), 177.7 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{18}\text{H}_{18}\text{N}_5$: 304.1557 [$\text{M} + \text{H}$] $^+$; found: 304.1557.

2-(Piperidin-1-yl)-4-(p-tolyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (23). Compound **23** was obtained according to the general procedure **B** using **9** (214 mg, 0.80 mmol, 1.0 eq.) and piperidine (0.17 mL, 1.71 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 100/0 to 90/10), **23** (230 mg, 86%) was obtained as a light yellow solid. Rf (PE/EA: 90/10): 0.51. M_p : 186–188 °C. IR (ATR diamond, cm^{-1}): 2929,



2848, 1589, 1564, 1549, 1496, 1385, 1291, 810. ^1H NMR (400 MHz, CDCl_3) δ : 1.60–1.69 (m, 6H, $3\times\text{CH}_2$), 1.69–1.79 (m, 2H, CH_2), 1.90–1.99 (m, 2H, CH_2), 2.39 (s, 3H, CH_3), 2.65–2.77 (m, 2H, N-CH_2), 3.06 (p, $J = 3.0$ Hz, 1H, CH), 3.09–3.20 (m, 2H, N-CH_2), 3.83–3.90 (m, 4H, $2\times\text{N-CH}_2$), 7.24 (d, $J = 8.0$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.20 (d, $J = 8.2$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.6 (CH_3), 25.1 (CH_2), 26.0 ($2\times\text{CH}_2$), 28.0 ($2\times\text{CH}_2$), 33.9 (CH), 45.1 ($2\times\text{N-CH}_2$), 49.5 ($2\times\text{N-CH}_2$), 128.8 ($2\times\text{CH}_{\text{Ar}}$), 129.8 ($2\times\text{CH}_{\text{Ar}}$), 130.2 (C_q), 134.4 (C_q), 139.5 (C_q), 154.9 (C_q), 159.6 (C_q), 175.0 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{21}\text{H}_{27}\text{N}_4$: 335.2230 [$\text{M} + \text{H}$] $^+$; found: 355.2229.

4-(4-Fluorophenyl)-2-(piperidin-1-yl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (24). Compound **24** was obtained according to the general procedure **B** using **10** (214 mg, 0.79 mmol, 1.0 eq.) and piperidine (0.17 mL, 1.71 mmol, 2.2 eq.). After purification by silica gel flash chromatography (PE/EA, 100/0 to 90/10), **24** (212 mg, 79%) was obtained as a beige solid. Rf (PE/EA: 90/10): 0.43. M_p : 196–198 °C. IR (ATR diamond, cm^{-1}) ν : 2936, 2863, 1578, 1503, 1384, 1225, 817, 796. ^1H NMR (400 MHz, CDCl_3) δ : 1.61–1.69 (m, 6H, $3\times\text{CH}_2$), 1.70–1.81 (m, 2H, CH_2), 1.89–2.01 (m, 2H, CH_2), 2.63–2.76 (m, 2H, N-CH_2), 3.06 (p, $J = 2.9$ Hz, 1H, CH), 3.10–3.20 (m, 2H, N-CH_2), 3.83–3.90 (m, 4H, $2\times\text{N-CH}_2$), 7.10 (t, $J = 8.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.39 (dd, $J = 8.9, 5.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 25.0 (CH_2), 26.0 ($2\times\text{CH}_2$), 27.9 ($2\times\text{CH}_2$), 33.8 (CH), 45.1 ($2\times\text{N-CH}_2$), 49.4 ($2\times\text{N-CH}_2$), 114.8 (CH_{Ar}), 115.0 (CH_{Ar}), 130.1 (C_q), 131.9 (CH_{Ar}), 132.0 (CH_{Ar}), 133.3 (C_q), 153.5 (C_q), 159.5 (C_q), 163.7 (d, $J = 249.1$ Hz, $\text{C}_q\text{-F}$), 175.3 (C_q). ^{19}F NMR (376 MHz, CDCl_3) δ : –111.9. HRMS (EI/MS): m/z calculated for $\text{C}_{20}\text{H}_{24}\text{FN}_4$: 339.1980 [$\text{M} + \text{H}$] $^+$; found: 339.1976.

General procedure C: Buchwald–Hartwig cross coupling via PyBroP activation. In a microwave vial, to an argon-degassed solution of **8** (253 mg, 1.00 mmol, 1.0 eq.) and PyBroP (559 mg, 1.20 mmol, 1.2 eq.) in 1,4-dioxane (10 mL), was added Et_3N (0.40 mL, 2.96 mmol, 3.0 eq.). The reaction was heated for 3 h at 100 °C. After cooling, K_2CO_3 (276 mg, 2.00 mmol, 2.0 eq.), the required amine (1.5.0 eq.), $\text{Pd}(\text{OAc})_2$ (22 mg, 0.10 mmol, 0.1 eq.) and Xantphos (116 mg, 0.20 mmol, 0.2 eq.) were added to the reaction mixture. The sealed tube was heated at 130 °C for 1 h under microwave irradiation. After cooling to room temperature, the solvent was evaporated under reduced pressure and the crude material was diluted in DCM (20 mL). The organic layer was washed with water (2×20 mL), dried over MgSO_4 , filtered, and concentrated under vacuum. The crude mixture was purified by flash chromatography on silica gel to obtain the desired compound.

1-(4-Phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-yl)piperidin-2-one (22). Compound **22** was obtained according to the general procedure **C** using 2-piperidone (0.14 mL, 1.51 mmol, 1.5 eq.). After purification by silica gel flash chromatography (DCM/MeOH, 95–5), **22** (133 mg, 40%) was obtained as a light yellow solid. Rf (DCM/MeOH: 95/5): 0.43. M_p : 216–218 °C. IR (ATR diamond, cm^{-1}) ν : 2943, 1670, 1562, 1377, 1153, 838, 776, 696, 624. ^1H NMR (400 MHz, CDCl_3) δ : 1.79 (m, 2H, CH_2), 1.91–2.10 (m, 6H, CH_2 , $2\times\text{CH}_2$, lactame), 2.63 (t, $J = 6.4$ Hz, 2H, $\text{C}(\text{O})\text{-CH}_2$), 2.73 (m, 2H, N-CH_2), 3.17–3.28 (m, 2H, N-CH_2), 3.34 (p, $J = 2.9$ Hz, 1H, CH), 3.97 (t, $J = 5.6$ Hz, 2H, N-

CH_2), 7.39–7.51 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.25–8.39 (m, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.4 (CH_2), 23.3 (CH_2), 27.7 ($2\times\text{CH}_2$), 33.5 (CH), 33.6 ($\text{C}(\text{O})\text{-CH}$), 48.8 ($2\times\text{N-CH}_2$), 49.2 (N-CH_2), 128.2 ($2\times\text{CH}_{\text{Ar}}$), 130.2 ($2\times\text{CH}_{\text{Ar}}$), 130.2 (CH_{Ar}), 135.5 (C_q), 138.3 (C_q), 156.3 (C_q), 157.7 (C_q), 170.9 ($\text{C}=\text{O}$), 176.5 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{20}\text{H}_{23}\text{N}_4\text{O}$: 335.1866 [$\text{M} + \text{H}$] $^+$; found: 335.1865.

1-(4-Phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-yl)pyrrolidin-2-one (25). Compound **25** was obtained according to general procedure **C** using 2-pyrrolidone (134 mg, 1.57 mmol, 1.5 eq.). After purification by silica gel flash chromatography (EA/PE, 80/20 to 90/10), **25** (125 mg, 39%) was obtained as a light yellow solid. Rf (EA/PE: 90/10): 0.18. M_p : 211–213 °C. IR (ATR diamond, cm^{-1}) ν : 2942, 1727, 1557, 1384, 1350, 1131, 775, 693, 622. ^1H NMR (400 MHz, CDCl_3) δ : 1.72–1.85 (m, 2H, CH_2), 1.96–2.08 (m, 2H, CH_2), 2.14 (p, $J = 7.7$ Hz, 2H, CH_2), 2.65–2.77 (m, 4H, N-CH_2 , $\text{C}(\text{O})\text{-CH}_2$), 3.16–3.27 (m, 2H, N-CH_2), 3.36 (p, $J = 2.9$ Hz, 1H, CH), 4.18 (t, $J = 7.1$ Hz, 2H, N-CH_2), 7.40–7.51 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.37–8.46 (m, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 17.9 (CH_2), 27.7 ($2\times\text{CH}_2$), 33.6 (CH), 33.8 ($\text{C}(\text{O})\text{-CH}_2$), 48.6 (N-CH_2), 48.9 ($2\times\text{N-CH}_2$), 128.3 ($2\times\text{CH}_{\text{Ar}}$), 130.2 ($2\times\text{CH}_{\text{Ar}}$), 130.3 (CH_{Ar}), 135.8 (C_q), 136.9 (C_q), 154.5 (C_q), 155.2 (C_q), 174.7 ($\text{C}=\text{O}$), 176.5 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{19}\text{H}_{21}\text{N}_4$: 321.1711 [$\text{M} + \text{H}$] $^+$; found: 321.1710.

N,4-Diphenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-amine (26). Compound **26** was obtained according to general procedure **C** using aniline (0.14 mL, 143 mg, 1.53 mmol, 1.5 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10 to 80/20), **26** (186 mg, 56%) was obtained as a white solid. Rf (PE/EA: 80/20): 0.27. M_p : 191–193 °C. IR (ATR diamond, cm^{-1}) ν : 2956, 1563, 1529, 1446, 1424, 1364, 768, 743, 685. ^1H NMR (400 MHz, CDCl_3) δ : 1.72–1.85 (m, 2H, CH_2), 1.96–2.08 (m, 2H, CH_2), 2.69–2.82 (m, 2H, N-CH_2), 3.12–3.26 (m, 3H, N-CH_2 , CH), 7.02 (t, $J = 7.4$ Hz, 1H, CH), 7.20 (s, 1H, NH), 7.35 (t, $J = 7.8$ Hz, 2H, $2\times\text{CH}$), 7.40–7.53 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 7.74 (d, $J = 7.7$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.33 (dd, $J = 1.8, 8.0$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 49.3 ($2\times\text{N-CH}_2$), 118.8 ($2\times\text{CH}_{\text{Ar}}$), 122.0 (CH_{Ar}), 128.2 ($2\times\text{CH}_{\text{Ar}}$), 129.0 ($2\times\text{CH}_{\text{Ar}}$), 129.9 (CH_{Ar}), 130.0 ($2\times\text{CH}_{\text{Ar}}$), 133.3 (C_q), 136.3 (C_q), 140.3 (C_q), 155.6 (C_q), 157.2 (C_q), 176.0 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{21}\text{H}_{21}\text{N}_4$: 329.1761 [$\text{M} + \text{H}$] $^+$; found: 329.1758.

N-(4-Methoxyphenyl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-amine (27). Compound **27** was obtained according to general procedure **C** using *p*-anisidine (187 mg, 1.51 mmol, 1.5 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10 to 80/20), **27** (173 mg, 48%) was obtained as a dark red solid. Rf (PE/EA: 80/20): 0.19. M_p : 223–225 °C. IR (ATR diamond, cm^{-1}) ν : 3242, 2920, 1566, 1508, 1357, 12369, 1038, 822, 696, 625. ^1H NMR (400 MHz, CDCl_3) δ : 1.71–1.83 (m, 2H, CH_2), 1.94–2.07 (m, 2H, CH_2), 2.68–2.81 (m, 2H, N-CH_2), 3.13 (p, $J = 2.9$ Hz, 1H, CH), 3.15–3.25 (m, 2H, N-CH_2), 3.81 (s, 3H, CH_3), 6.91 (d, $J = 9.2$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.04 (s, 1H, NH), 7.39–7.51 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 7.61 (d, $J = 9.0$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.31 (dd, $J = 1.6, 7.9$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 49.3 ($2\times\text{N-CH}_2$), 55.7 (CH_3), 114.3 ($2\times\text{CH}_{\text{Ar}}$), 120.9 ($2\times\text{CH}_{\text{Ar}}$), 128.2 ($2\times\text{CH}_{\text{Ar}}$), 129.8 (CH_{Ar}), 129.9 ($2\times\text{CH}_{\text{Ar}}$), 132.9 (C_q), 133.6 (C_q), 136.6 (C_q), 155.1 (C_q),



155.6 (C_q), 157.5 (C_q), 176.0 (C_q). HRMS (EI/MS): *m/z* calculated for C₂₂H₂₃N₄O: 359.1866 [M + H]⁺; found: 359.1863.

4-Phenyl-N-(*p*-tolyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2-amine (21). Compound 21 was obtained according to general procedure C using *p*-toluidine (165 mg, 1.54 mmol, 1.5 eq.). After purification by silica gel flash chromatography (PE/EA, 100/0 to 80/20), 21 (165 mg, 48%) was obtained as a light orange solid. Rf (PE/EA: 80/20): 0.20. *M*_p: 222–224 °C. IR (ATR diamond, cm⁻¹): 3294, 2943, 2867, 1589, 1519, 1425, 1355, 780, 698, 624. ¹H NMR (400 MHz, CDCl₃) δ: 1.72–1.83 (m, 2H, CH₂), 1.95–2.07 (m, 2H, CH₂), 2.34 (s, 3H, CH₃), 2.69–2.81 (m, 2H, N-CH₂), 3.11–3.25 (m, 3H, N-CH₂, CH), 7.13 (s, 1H, NH), 7.15 (d, *J* = 8.2 Hz, 2H, 2xCH_{Ar}), 7.40–7.52 (m, 3H, 3xCH_{Ar}), 7.61 (d, *J* = 8.4 Hz, 2H, 2xCH_{Ar}), 8.32 (dd, *J* = 1.7, 8.0 Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ: 20.9 (CH₃), 27.8 (2xCH₂), 33.7 (CH), 49.3 (2xN-CH₂), 119.0 (2xCH_{Ar}), 128.2 (2xCH_{Ar}), 129.4 (2xCH_{Ar}), 129.8 (CH_{Ar}), 129.9 (2xCH_{Ar}), 131.5 (C_q), 133.1 (C_q), 136.4 (C_q), 137.7 (C_q), 155.6 (C_q), 157.3 (C_q), 175.9 (C_q). HRMS (EI/MS): *m/z* calculated for C₂₂H₂₃N₄: 343.1917 [M + H]⁺; found: 343.1917.

4-Phenyl-N-(*m*-tolyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2-amine (28). Compound 28 was obtained according to the general procedure C using *m*-toluidine (0.16 mL, 1.47 mmol, 1.5 eq.). After purification by silica gel flash chromatography (DCM/PE, 80/20), 28 (106 mg, 31%) was obtained as a light yellow solid. Rf (DCM/PE: 80/20): 0.14. *M*_p: 230–232 °C. IR (ATR diamond, cm⁻¹): 3226, 2940, 1562, 1531, 1488, 1422, 1357, 1165, 770, 690, 625. ¹H NMR (400 MHz, CDCl₃) δ: 1.73–1.85 (m, 2H, CH₂), 1.96–2.08 (m, 2H, CH₂), 2.38 (s, 3H, CH₃), 2.69–2.82 (m, 2H, N-CH₂), 3.13–3.26 (m, 3H, N-CH₂, CH), 6.84 (d, *J* = 7.4 Hz, 1H, CH_{Ar}), 7.12 (s, 1H, NH), 7.23 (t, *J* = 7.8 Hz, 1H, CH_{Ar}), 7.40–7.51 (m, 3H, 3xCH_{Ar}), 7.54 (s, 1H, CH_{Ar}), 7.58 (dd, *J* = 8.1, 2.2 Hz, 1H, CH_{Ar}), 8.31–8.38 (m, 2H, CH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ: 21.8 (CH₃), 27.8 (2xCH₂), 33.7 (CH), 49.3 (2xN-CH₂), 115.9 (CH_{Ar}), 119.5 (CH_{Ar}), 122.9 (CH_{Ar}), 128.2 (2xCH_{Ar}), 128.8 (CH_{Ar}), 129.9 (CH_{Ar}), 130.0 (2xCH_{Ar}), 133.2 (C_q), 136.4 (C_q), 138.7 (C_q), 140.2 (C_q), 155.5 (C_q), 157.2 (C_q), 176.0 (C_q). HRMS (EI/MS): *m/z* calculated for C₂₂H₂₃N₄: 343.1917 [M + H]⁺; found: 343.1914.

4-Phenyl-N-(*o*-tolyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2-amine (29). Compound 29 was obtained according to the general procedure C using *o*-toluidine (0.10 mL, 1.46 mmol, 1.5 eq.). After purification by silica gel flash chromatography (DCM/PE, 70/30 to 80/20), 29 (54 mg, 15%) was obtained as a beige solid. Rf (DCM/PE: 70/30): 0.16. *M*_p: 208–210 °C. IR (ATR diamond, cm⁻¹): 3212, 2946, 1564, 1529, 1361, 744, 684, 625. ¹H NMR (400 MHz, CDCl₃) δ: 1.72–1.85 (m, 2H, CH₂), 1.96–2.07 (m, 2H, CH₂), 2.37 (s, 3H, CH₃), 2.70–2.82 (m, 2H, N-CH₂), 3.11–3.26 (m, 3H, N-CH₂, CH), 6.88 (s, 1H, NH), 6.99 (td, *J* = 7.4, 1.3 Hz, 1H, CH_{Ar}), 7.21 (d, *J* = 7.3 Hz, 1H, CH_{Ar}), 7.27 (td, *J* = 7.8, 1.6 Hz, 1H, CH_{Ar}), 7.39–7.51 (m, 3H, 3xCH_{Ar}), 8.29–8.36 (m, 3H, 2xCH_{Ar}, CH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ: 18.3 (CH₃), 27.8 (2xCH₂), 33.7 (CH), 49.3 (2xN-CH₂), 120.4 (CH_{Ar}), 122.6 (CH_{Ar}), 126.7 (CH_{Ar}), 127.2 (C_q), 128.2 (2xCH_{Ar}), 129.8 (CH_{Ar}), 130.0 (2xCH_{Ar}), 130.4 (CH_{Ar}), 133.2 (C_q), 136.3 (C_q), 138.3 (C_q), 155.6 (C_q), 157.5 (C_q), 176.0 (C_q). HRMS (EI/MS): *m/z* calculated for C₂₂H₂₃N₄: 343.1917 [M + H]⁺; found: 343.1916.

4-Phenyl-N-(4-(trifluoromethyl)phenyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2-amine (30). Compound 30 was obtained according to general procedure C using 4-(trifluoromethyl)aniline (0.19 mL, 243 mg, 1.50 mmol, 1.5 eq.). After purification by silica gel flash chromatography (DCM/PE, 80/20), 30 (212 mg, 56%) was obtained as a beige solid. Rf (DCM/PE: 80/20): 0.20. *M*_p: 182–184 °C. IR (ATR diamond, cm⁻¹): 3280, 2957, 1534, 1415, 1321, 1109, 1066, 836, 625. ¹H NMR (400 MHz, CDCl₃) δ: 1.73–1.84 (m, 2H, CH₂), 1.98–2.09 (m, 2H, CH₂), 2.69–2.82 (m, 2H, N-CH₂), 3.14–3.28 (m, 3H, N-CH₂, CH), 7.36 (s, 1H, NH), 7.44–7.55 (m, 3H, 3xCH_{Ar}), 7.59 (d, *J* = 8.6 Hz, 2H, 2xCH_{Ar}), 7.85 (d, *J* = 8.5 Hz, 2H, 2xCH_{Ar}), 8.29–8.36 (m, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ: 27.8 (2xCH₂), 33.7 (CH), 49.2 (2xN-CH₂), 117.9 (2xCH_{Ar}), 123.3 (C_q), 124.8 (d, *J* = 241.0 Hz, C_q-CF₃), 126.3 (q, *J* = 3.9 Hz, 2xCH_{Ar}), 128.3 (2xCH_{Ar}), 130.0 (2xCH_{Ar}), 130.1 (CH_{Ar}), 134.1 (C_q), 136.0 (C_q), 143.4 (d, *J* = 0.9 Hz, CF₃), 155.8 (C_q), 156.6 (C_q), 176.3 (C_q). ¹⁹F NMR (376 MHz, CDCl₃) δ: -61.65. HRMS (EI/MS): *m/z* calculated for C₂₂H₂₀F₃N₄: 397.1635 [M + H]⁺; found: 397.1633.

4-(4-Phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2-yl)amino)benzotrile (31). Compound 31 was obtained according to the general procedure C using 4-amino-benzotrile (177 mg, 1.50 mmol, 1.5 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10 to 70/30), 31 (124 mg, 35%) was obtained as a light yellow solid. Rf (DCM/PE: 80/20): 0.16. *M*_p: 234–236 °C. IR (ATR diamond, cm⁻¹): 3399, 2923, 2214, 1566, 1517, 1413, 1357, 1171, 834, 687, 535. ¹H NMR (400 MHz, CDCl₃) δ: 1.71–1.84 (m, 2H, CH₂), 1.98–2.11 (m, 2H, CH₂), 2.68–2.81 (m, 2H, N-CH₂), 3.15–3.28 (m, 3H, N-CH₂, CH), 7.43–7.55 (m, 4H, 3xCH_{Ar}, NH), 7.60 (d, *J* = 8.8 Hz, 2H, 2xCH_{Ar}), 7.85 (d, *J* = 8.8 Hz, 2H, 2xCH_{Ar}), 8.25–8.35 (m, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ: 27.8 (2xCH₂), 33.7 (CH), 49.1 (2xN-CH₂), 104.0 (C_q), 118.0 (2xCH_{Ar}), 119.7 (C_q), 128.3 (2xCH_{Ar}), 129.9 (2xCH_{Ar}), 130.2 (CH_{Ar}), 133.3 (2xCH_{Ar}), 134.5 (C_q), 135.8 (C_q), 144.3 (C_q), 155.9 (C_q), 156.2 (C_q), 176.5 (C_q). HRMS (EI/MS): *m/z* calculated for C₂₂H₂₀N₅: 354.1713 [M + H]⁺; found: 354.1710.

N-(4-Nitrophenyl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2-amine (32). Compound 32 was obtained according to general procedure C using 4-nitroaniline (208 mg, 1.50 mmol, 1.5 eq.). The obtained solid was washed with DCM and dried under *vacuo* to afford 32 (148 mg, 39%) as a yellow solid. Rf (PE/EA: 80/20): 0.17. *M*_p: >260 °C. IR (ATR diamond, cm⁻¹): 3386, 2940, 1530, 1488, 1416, 1324, 1111, 840, 686, 584. ¹H NMR (400 MHz, CDCl₃) δ: 1.74–1.85 (m, 2H, CH₂), 2.01–2.12 (m, 2H, CH₂), 2.70–2.81 (m, 2H, N-CH₂), 3.13–3.29 (m, 3H, N-CH₂, CH), 7.45–7.54 (m, 3H, 3xCH_{Ar}), 7.56 (s, 1H, NH), 7.89 (d, *J* = 9.2 Hz, 2H, 2xCH_{Ar}), 8.24 (d, *J* = 9.2 Hz, 2H, 2xCH_{Ar}), 8.32 (dd, *J* = 2.3, 7.3 Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ: 27.8 (2xCH₂), 33.7 (CH), 49.1 (2xN-CH₂), 117.3 (2xCH_{Ar}), 125.5 (2xCH_{Ar}), 128.4 (2xCH_{Ar}), 130.0 (2xCH_{Ar}), 130.3 (CH_{Ar}), 134.9 (C_q), 135.7 (C_q), 141.6 (C_q), 146.3 (C_q), 156.0 (C_q), 156.0 (C_q), 176.6 (C_q). HRMS (EI/MS): *m/z* calculated for C₂₁H₂₀N₅O₂: 374.1612 [M + H]⁺; found: 374.1607.

4-Phenyl-N-(pyridin-3-yl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2-amine (33). Compound 33 was obtained according



to the general procedure C using 3-aminopyridine (142 mg, 1.5 mmol, 1.5 eq.). After purification by silica gel flash chromatography (EA/PE, 70/30), **33** (115 mg, 34%) was obtained as a light yellow solid. Rf (EA/PE: 70/30): 0.30. M_p : 211–213 °C. IR (ATR diamond, cm^{-1}): 2954, 1531, 1428, 1386, 1353, 692, 623. ^1H NMR (400 MHz, CDCl_3) δ : 1.71–1.83 (m, 2H, CH_2), 1.97–2.10 (m, 2H, CH_2), 2.68–2.81 (m, 2H, N- CH_2), 3.12–3.26 (m, 3H; N- CH_2 , CH), 7.27 (dd, $J = 8.3, 4.8$ Hz, 1H, CH_{Ar}), 7.36 (s, 1H, NH), 7.40–7.54 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.20–8.37 (m, 4H, $2\times\text{CH}_{\text{Ar}}$, $2\times\text{CH}_{\text{Ar}}$), 8.83 (d, $J = 2.2$ Hz, 1H, CH_{Ar}). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 49.2 ($2\times\text{N-CH}_2$), 123.5 (CH_{Ar}), 125.4 (CH_{Ar}), 128.3 ($2\times\text{CH}_{\text{Ar}}$), 130.0 ($2\times\text{CH}_{\text{Ar}}$), 130.1 (CH_{Ar}), 133.9 (C_q), 136.0 (C_q), 137.0 (C_q), 140.7 (CH_{Ar}), 143.0 (CH_{Ar}), 155.8 (C_q), 156.8 (C_q), 176.3 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{20}\text{H}_{20}\text{N}_5$: 330.1713 [$\text{M} + \text{H}$] $^+$; found: 330.1714.

N-(6-Methoxypyridin-3-yl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyridin[3,2-*d*]pyrimidin-2-amine (**34**). Compound **34** was obtained according to the general procedure C using 5-amino-2-methoxypyridine (0.12 mL, 189 mg, 1.52 mmol, 1.5 eq.). After purification by silica gel flash chromatography (PE/EA, 50/50), **34** (102 mg, 28%) was obtained as a light orange solid. Rf (PE/EA: 50/50): 0.52. M_p : 183–185 °C. IR (ATR diamond, cm^{-1}): 1942, 1537, 1490, 1348, 1278, 1035, 831, 691, 624. ^1H NMR (400 MHz, CDCl_3) δ : 1.73–1.81 (m, 2H, CH_2), 1.95–2.07 (m, 2H, CH_2), 2.68–2.80 (m, 2H, N- CH_2), 3.13 (p, $J = 2.9$ Hz, 1H, CH), 3.15–3.25 (m, 2H, N- CH_2), 3.94 (s, 3H, O- CH_3), 6.77 (d, $J = 8.9$ Hz, 1H, CH_{Ar}), 6.95 (s, 1H, NH), 7.39–7.51 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.04 (dd, $J = 8.9, 2.8$ Hz, 1H, CH_{Ar}), 8.22–8.31 (m, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.42 (d, $J = 2.7$ Hz, 1H, CH_{Ar}). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 49.3 ($2\times\text{N-CH}_2$), 53.6 (O- CH_3), 110.5 (CH_{Ar}), 128.2 ($2\times\text{CH}_{\text{Ar}}$), 129.9 ($2\times\text{CH}_{\text{Ar}}$), 129.9 (CH_{Ar}), 131.0 (C_q), 131.7 (CH_{Ar}), 133.4 (C_q), 136.1 (C_q), 137.8 (CH_{Ar}), 155.8 (C_q), 157.3 (C_q), 160.0 (C_q), 176.2 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{21}\text{H}_{22}\text{N}_5\text{O}$: 360.1819 [$\text{M} + \text{H}$] $^+$; found: 360.1819.

N-Phenyl-4-(*p*-tolyl)-7,8-dihydro-6H-5,8-ethanopyridin[3,2-*d*]pyrimidin-2-amine (**35**)

Compound **35** was obtained according to general procedure C using **9** (274 mg, 1.02 mmol, 1.0 eq.) and aniline (0.14 mL, 1.53 mmol, 1.5 eq.). After purification by silica gel flash chromatography (PE/EA: 90/10 to 80/20), **35** (156 mg, 44%) was obtained as a beige solid. Rf (PE/EA: 80/20): 0.50. M_p : 195–197 °C. IR (ATR diamond, cm^{-1}): 3229, 2960, 1574, 1531, 1429, 1362, 1171, 812, 742, 688. ^1H NMR (400 MHz, CDCl_3) δ : 1.71–1.84 (m, 2H, CH_2), 1.95–2.07 (m, 2H, CH_2), 2.42 (s, 3H, CH_3), 2.68–2.81 (m, 2H, N- CH_2), 3.12–3.25 (m, 3H, N- CH_2 , CH), 7.01 (tt, $J = 7.3, 1.2$ Hz, 1H, CH_{Ar}), 7.15 (s, 1H, NH), 7.29 (d, $J = 7.9$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.30–7.38 (m, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.70–7.77 (m, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.24 (d, $J = 8.3$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.6 (CH_3), 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 49.3 ($2\times\text{N-CH}_2$), 118.7 ($2\times\text{CH}_{\text{Ar}}$), 121.9 (CH_{Ar}), 129.0 ($2\times\text{CH}_{\text{Ar}}$), 129.0 ($2\times\text{CH}_{\text{Ar}}$), 129.9 ($2\times\text{CH}_{\text{Ar}}$), 133.1 (C_q), 133.5 (C_q), 140.0 (C_q), 140.4 (C_q), 155.7 (C_q), 157.1 (C_q), 175.8 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{22}\text{H}_{23}\text{N}_4$: 343.1917 [$\text{M} + \text{H}$] $^+$; found: 343.1916.

4-(*p*-Tolyl)-*N*-(4-(trifluoromethyl)phenyl)-7,8-dihydro-6H-5,8-ethanopyridin[3,2-*d*]pyrimidin-2-amine (**36**). Compound **36** was obtained according to general procedure C using **9** (264 mg, 0.98 mmol, 1.0 eq.) and 4-(trifluoromethyl)aniline (0.19 mL,

1.50 mmol, 1.5 eq.). After purification by silica gel flash chromatography (PE/EA: 90/10 to 80/20), **36** (200 mg, 49%) was obtained as a beige solid. Rf (PE/EA: 80/20): 0.20. M_p : 195–197 °C. IR (ATR diamond, cm^{-1}): 3270, 2962, 1576, 1536, 1318, 1100, 1064, 838. ^1H NMR (400 MHz, CDCl_3) δ : 1.71–1.84 (m, 2H, CH_2), 1.97–2.09 (m, 2H, CH_2), 2.43 (s, 3H, CH_3), 2.68–2.81 (m, 2H, N- CH_2), 3.13–3.27 (m, 3H, N- CH_2 , CH), 7.30 (d, $J = 8.0$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.37 (s, 1H, NH), 7.58 (d, $J = 8.4$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.85 (d, $J = 8.5$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.24 (d, $J = 8.3$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.5 (CH_3), 27.7 ($2\times\text{CH}_2$), 33.6 (CH), 49.0 ($2\times\text{N-CH}_2$), 117.7 ($2\times\text{CH}_{\text{Ar}}$), 124.6 (d, $J = 252.1$ Hz, $\text{C}_q\text{-CF}_3$), 126.1 (q, $J = 3.8$ Hz, $2\times\text{CH}_{\text{Ar}}$), 128.9 ($2\times\text{CH}_{\text{Ar}}$), 129.8 ($2\times\text{CH}_{\text{Ar}}$), 133.1 (C_q), 133.8 (C_q), 140.2 (C_q), 143.3 (d, $J = 0.6$ Hz, CF_3), 155.7 (C_q), 156.4 (C_q), 176.0 (C_q). ^{19}F NMR (376 MHz, CDCl_3) δ : –61.63. HRMS (EI/MS): m/z calculated for $\text{C}_{23}\text{H}_{22}\text{F}_3\text{N}_4$: 411.1791 [$\text{M} + \text{H}$] $^+$; found: 411.1791.

General procedure D: Suzuki-Miyaura cross-coupling. In a microwave vial, to an argon-degassed solution of **8** (200 mg, 0.79 mmol, 1.0 eq.) and PyBroP (446 mg, 0.96 mmol, 1.2 eq.) in 1,4-dioxane (8 mL), was added Et_3N (0.32 mL, 239 mg, 2.36 mmol, 3.0 eq.) and the reaction was heated for 3 h at 100 °C. After cooling, a solution of K_3PO_4 (849 mg, 4.00 mmol, 5.0 eq.) in H_2O (2 mL), the required arylboronic acid (2.0 eq.), $\text{Pd}(\text{OAc})_2$ (18 mg, 0.08 mmol, 0.1.0 eq.) and RuPhos (74 mg, 0.16 mmol, 0.2 eq.) were added to the reaction mixture. The sealed tube was heated at 150 °C for 1 h under microwave irradiation. After cooling to room temperature, the solvent was evaporated under reduced pressure and the crude material was diluted in DCM (20 mL). The organic layer was washed with water (2×20 mL), dried over MgSO_4 , filtered, and concentrated under vacuum. The crude mixture was purified by flash chromatography on silica gel to obtain the desired compound.

4-Phenyl-2-(*p*-tolyl)-7,8-dihydro-6H-5,8-ethanopyridin[3,2-*d*]pyrimidine (**39**). Compound **39** was obtained according to the general procedure D using *p*-tolylboronic acid (239 mg, 1.60 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **39** (182 mg, 70%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.40. M_p : 192–194 °C. IR (ATR diamond, cm^{-1}): 2963, 2924, 2871, 1550, 1387, 1170, 772, 689, 623. ^1H NMR (400 MHz, CDCl_3) δ : 1.76–1.87 (m, 2H, CH_2), 2.01–2.13 (m, 2H, CH_2), 2.43 (s, 3H, CH_3), 2.77 (td, $J = 4.9, 11.5$ Hz, 2H, N- CH_2), 3.20–3.32 (m, 2H, N- CH_2), 3.38 (p, $J = 2.8, 3.2$ Hz, 1H, CH), 7.30 (d, $J = 7.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.43–7.56 (m, 3H, $3\times\text{CH}_{\text{Ar}}$), 8.47 (dd, $J = 8.1, 12.2$ Hz, 4H, $4\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.6 (CH_3), 27.9 ($2\times\text{CH}_2$), 33.7 (CH), 48.9 ($2\times\text{N-CH}_2$), 128.2 ($2\times\text{CH}_{\text{Ar}}$), 128.3 ($2\times\text{CH}_{\text{Ar}}$), 129.3 ($2\times\text{CH}_{\text{Ar}}$), 130.0 (CH_{Ar}), 130.2 ($2\times\text{CH}_{\text{Ar}}$), 135.7 (C_q), 136.4 (C_q), 139.0 (C_q), 140.3 (C_q), 154.7 (C_q), 161.2 (C_q), 175.1 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{22}\text{H}_{22}\text{N}_3$: 328.1808 [$\text{M} + \text{H}$] $^+$; found: 328.1808.

2,4-Diphenyl-7,8-dihydro-6H-5,8-ethanopyridin[3,2-*d*]pyrimidine (**40**). Compound **40** was obtained according to general procedure D using phenylboronic acid (195 mg, 1.60 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **40** (171 mg, 68%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.30. M_p : 195–197 °C. IR (ATR diamond, cm^{-1}): 2945, 2921, 1553, 1389, 768, 692, 624. ^1H NMR (400 MHz, CDCl_3) δ : 1.75–1.89 (m, 2H, CH_2), 2.02–2.14 (m, 2H, CH_2), 2.72–2.84 (m,



2H, N-CH₂), 3.21–3.32 (m, 2H, N-CH₂), 3.40 (p, $J = 2.9$ Hz, 1H, CH), 7.42–7.56 (m, 6H, 6xCH_{Ar}), 8.50 (dd, $J = 1.7, 8.1$ Hz, 2H, 2xCH_{Ar}), 8.57 (dd, $J = 1.8, 8.0$ Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 27.8 (2xCH₂), 33.7 (CH), 48.9 (2xN-CH₂), 128.2 (2xCH_{Ar}), 128.3 (2xCH_{Ar}), 128.5 (2xCH_{Ar}), 130.0 (CH_{Ar}), 130.2 (2xCH_{Ar}), 136. (C_q), 138.4 (C_q), 139.3 (C_q), 154.8 (C_q), 161.1 (C_q), 175.2 (C_q). HRMS (EI/MS): m/z calculated for C₂₁H₂₀N₃: 314.1652 [M + H]⁺; found: 314.1655.

4-Phenyl-2-(*m*-tolyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidine (41). Compound 41 was obtained according to general procedure D using *m*-tolylboronic acid (215 mg, 1.58 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 41 (189 mg, 73%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.27. M_p : 191–193 °C. IR (ATR diamond, cm⁻¹) ν : 2961, 2946, 2869, 1553, 1385, 1376, 771, 733, 690, 624. ¹H NMR (400 MHz, CDCl₃) δ : 1.75–1.88 (m, 2H, CH₂), 2.02–2.14 (m, 2H, CH₂), 2.47 (s, 3H, CH₃), 2.71–2.84 (m, 2H, N-CH₂), 3.21–3.32 (m, 2H, N-CH₂), 3.39 (p, $J = 3.0$ Hz, 1H, CH), 7.28 (d, $J = 7.5$ Hz, 1H, CH_{Ar}), 7.39 (t, $J = 7.9$ Hz, 1H, CH_{Ar}), 7.43–7.56 (m, 3H, 3xCH_{Ar}), 8.36 (d, $J = 6.9$ Hz, 2H, 2xCH_{Ar}), 8.48 (dt, $J = 1.5, 2.3, 6.4$ Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 21.7 (CH₃), 27.9 (2xCH₂), 33.7 (CH), 48.9 (2xN-CH₂), 125.6 (CH_{Ar}), 128.3 (2xCH_{Ar}), 128.5 (CH_{Ar}), 128.8 (CH_{Ar}), 130.0 (CH_{Ar}), 130.2 (2xCH_{Ar}), 131.1 (CH_{Ar}), 136.3 (C_q), 138.1 (C_q), 138.3 (C_q), 139.2 (C_q), 154.9 (C_q), 161.3 (C_q), 175.1 (C_q). HRMS (EI/MS): m/z calculated for C₂₂H₂₂N₃: 328.1808 [M + H]⁺; found: 328.1813.

4-Phenyl-2-(*o*-tolyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidine (42). Compound 42 was obtained according to general procedure D using *o*-tolylboronic acid (215 mg, 1.58 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 42 (196 mg, 76%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.22. M_p : 228–230 °C. IR (ATR diamond, cm⁻¹) ν : 2944, 2869, 1552, 1387, 1131, 844, 767, 736, 695, 623. ¹H NMR (400 MHz, CDCl₃) δ : 1.79–1.88 (m, 2H, CH₂), 2.03–2.14 (m, 2H, CH₂), 2.66 (s, 3H, CH₃), 2.75–2.87 (m, 2H, N-CH₂), 3.22–3.34 (m, 2H, N-CH₂), 3.38 (p, $J = 2.9$ Hz, 1H, CH), 7.27–7.38 (m, 3H, 3xCH_{Ar}), 7.38–7.55 (m, 3H, 2xCH_{Ar}, CH_{Ar}), 7.87–7.94 (m, 1H, CH_{Ar}), 8.44 (dd, $J = 1.8, 8.0$ Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 21.5 (CH₃), 27.9 (2xCH₂), 33.6 (CH), 48.9 (2xN-CH₂), 126.0 (CH_{Ar}), 128.3 (2xCH_{Ar}), 129.1 (CH_{Ar}), 130.0 (CH_{Ar}), 130.2 (2xCH_{Ar}), 130.6 (CH_{Ar}), 131.3 (CH_{Ar}), 136.2 (C_q), 137.3 (C_q), 138.5 (C_q), 138.9 (C_q), 154.6 (C_q), 164.1 (C_q), 174.9 (C_q). HRMS (EI/MS): m/z calculated for C₂₂H₂₂N₃: 328.1808 [M + H]⁺; found: 328.1813.

2-(4-Methoxyphenyl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidine (43). Compound 43 was obtained according to general procedure D using 4-methoxyphenylboronic acid (244 mg, 1.60 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 43 (188 mg, 69%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.24. M_p : 204–206 °C. IR (ATR diamond, cm⁻¹) ν : 2960, 2935, 1549, 1387, 1247, 1031, 772, 694. ¹H NMR (400 MHz, CDCl₃) δ : 1.75–1.87 (m, 2H, CH₂), 2.01–2.12 (m, 2H, CH₂), 2.77 (td, $J = 5.0, 11.4$ Hz, 2H, N-CH₂), 3.20–3.31 (m, 2H, N-CH₂), 3.36 (p, $J = 3.0$ Hz, 1H, CH), 3.89 (s, 3H, O-CH₃), 7.01 (d, $J = 8.5$ Hz, 2H, 2xCH_{Ar}), 7.42–7.55 (m, 3H, 3xCH_{Ar}), 8.47 (d, $J = 7.7$ Hz, 2H, 2xCH_{Ar}), 8.52 (d, $J = 8.4$ Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 27.9 (2xCH₂), 33.7 (CH),

49.0 (2xN-CH₂), 55.4 (O-CH₃), 113.9 (2xCH_{Ar}), 128.2 (2xCH_{Ar}), 129.9 (2xCH_{Ar}), 129.9 (CH_{Ar}), 130.2 (2xCH_{Ar}), 131.1 (C_q), 136.4 (C_q), 138.6 (C_q), 154.7 (C_q), 160.9 (C_q), 161.5 (C_q), 175.0 (C_q). HRMS (EI/MS): m/z calculated for C₂₂H₂₂N₃O: 344.1757 [M + H]⁺; found: 344.1759.

4-(4-Phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidin-2-yl)phenol (44). Compound 44 was obtained according to general procedure D using 4-hydroxyphenylboronic acid (219 mg, 1.59 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 80/20), 44 (141 mg, 54%) was obtained as a white solid. Rf (PE/EA: 80/20): 0.17. M_p : 254–256 °C. IR (ATR diamond, cm⁻¹) ν : 3059, 2942, 2675, 1610, 1552, 1400, 1238, 1166, 774, 688, 625. ¹H NMR (400 MHz, DMSO-*d*₆) δ : 1.61–1.75 (m, 2H, CH₂), 1.97–2.11 (m, 2H, CH₂), 2.58–2.71 (m, 2H, N-CH₂), 3.14–3.21 (m, 2H, N-CH₂), 3.23 (p, $J = 2.3$ Hz, 1H, CH), 6.89 (td, $J = 1.7, 8.7$ Hz, 2H, 2xCH_{Ar}), 7.45–7.57 (m, 3H, 3xCH_{Ar}), 8.34 (td, $J = 2.0, 8.7$ Hz, 2H, 2xCH_{Ar}), 8.39 (dd, $J = 1.9, 7.8$ Hz, 2H, 2xCH_{Ar}), 9.88 (s, 1H, OH). ¹³C NMR (101 MHz, DMSO-*d*₆) δ : 27.0 (2xCH₂), 33.0 (CH), 48.2 (2xN-CH₂), 115.3 (2xCH_{Ar}), 128.0 (2xCH_{Ar}), 128.6 (C_q), 129.5 (2xCH_{Ar}), 129.8 (CH_{Ar}), 129.8 (CH_{Ar}), 135.7 (C_q), 138.2 (C_q), 153.5 (C_q), 159.6 (C_q), 159.8 (C_q), 175.1 (C_q). HRMS (EI/MS): m/z calculated for C₂₁H₂₀N₃O: 330.1601 [M + H]⁺; found: 330.1602.

4-Phenyl-2-(4-((tetrahydro-2H-pyran-2-yl)oxy)phenyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidine (45). Compound 45 was obtained according to general procedure D using 4-(tetrahydro-2H-pyran-2-yloxy)phenylboronic acid (358 mg, 1.61 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 80/20), 45 (230 mg, 69%) was obtained as a white solid. Rf (PE/EA: 80/20): 0.34. M_p : 210–212 °C. IR (ATR diamond, cm⁻¹) ν : 2940, 2872, 1551, 1386, 1236, 1163, 1113, 958, 920, 768, 693. ¹H NMR (400 MHz, CDCl₃) δ : 1.57–1.75 (m, 3H, 3xCH_{THP}), 1.76–1.85 (m, 2H, CH₂), 1.86–1.95 (m, 2H, 2xCH_{THP}), 1.97–2.12 (m, 3H, CH₂, CH_{THP}), 2.70–2.83 (m, 2H, N-CH₂), 3.19–3.31 (m, 2H, N-CH₂), 3.36 (p, $J = 2.9$ Hz, 1H, CH), 3.59–3.68 (m, 1H, CH_{THP}), 3.89–3.99 (m, 1H, CH_{THP}), 5.52 (t, $J = 3.3$ Hz, 1H, O-CH-O), 7.15 (d, $J = 8.8$ Hz, 2H, 2xCH_{Ar}), 7.44–7.55 (m, 3H, 3xCH_{Ar}), 8.43–8.53 (m, 4H, 2xCH_{Ar}, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 18.9 (CH_{2,THP}), 25.3 (CH_{2,THP}), 27.9 (2xCH₂), 30.4 (CH_{2,THP}), 33.7 (CH), 48.9 (2xN-CH₂), 62.2 (CH_{2,THP}), 96.3 (O-CH-O), 116.3 (2xCH_{Ar}), 128.2 (2xCH_{Ar}), 129.8 (2xCH_{Ar}), 129.9 (CH_{Ar}), 130.2 (2xCH_{Ar}), 131.9 (C_q), 136.4 (C_q), 138.7 (C_q), 154.7 (C_q), 159.0 (C_q), 160.9 (C_q), 175.0 (C_q). HRMS (EI/MS): m/z calculated for C₂₆H₂₈N₃O₂: 414.2176 [M + H]⁺; found: 414.2174.

2-(2-Naphthalen-2-yl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-*d*]pyrimidine (46). Compound 46 was obtained according to general procedure D using 2-naphthylboronic acid (275 mg, 1.60 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 46 (196 mg, 67%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.35. M_p : 210–212 °C. IR (ATR diamond, cm⁻¹) ν : 2949, 2868, 1552, 1391, 1380, 773, 755, 700, 625. ¹H NMR (400 MHz, CDCl₃) δ : 1.80–1.92 (m, 2H, CH₂), 2.05–2.16 (m, 2H, CH₂), 2.74–2.87 (m, 2H, N-CH₂), 3.23–3.34 (m, 2H, N-CH₂), 3.45 (p, $J = 2.9$ Hz, 1H, CH), 7.46–7.60 (m, 5H, 3xCH_{Ar}, 2xCH_{Ar}), 7.86–7.93 (m, 1H, CH_{Ar}), 7.97 (d, $J = 8.7$ Hz, 1H, CH_{Ar}), 8.01–8.09 (m, 1H, CH_{Ar}), 8.50–8.57 (m, 2H, 2xCH_{Ar}), 8.71 (dd, $J = 1.7, 8.6$ Hz, 1H, CH_{Ar}), 9.10 (s, 1H, CH_{Ar}). ¹³C NMR (101 MHz,



CDCl_3) δ : 27.9 (2xCH₂), 33.7 (CH), 48.9 (2xN-CH₂), 125.6 (CH_{Ar}), 126.2 (CH_{Ar}), 126.9 (CH_{Ar}), 127.8 (CH_{Ar}), 128.1 (CH_{Ar}), 128.3 (2xCH_{Ar}), 128.3 (CH_{Ar}), 129.3 (CH_{Ar}), 130.1 (CH_{Ar}), 130.3 (CH_{Ar}), 133.5 (C_q), 134.6 (C_q), 135.7 (C_q), 136.3 (C_q), 139.3 (C_q), 155.0 (C_q), 161.0 (C_q), 175.3 (C_q). HRMS (EI/MS): m/z calculated for C₂₅H₂₂N₃: 364.1808 [M + H]⁺; found: 364.1812.

2-(4-Fluorophenyl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (47). Compound 47 was obtained according to general procedure D using 4-fluorophenylboronic acid (224 mg, 1.60 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 47 (186 mg, 70%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.42. M_p : 178–180 °C. IR (ATR diamond, cm⁻¹) ν : 2922, 2864, 1601, 1555, 1389, 1151, 832, 768, 688, 622. ¹H NMR (400 MHz, CDCl₃) δ : 1.75–1.87 (m, 2H, CH₂), 2.02–2.14 (m, 2H, CH₂), 2.71–2.83 (m, 2H, N-CH₂), 3.21–3.32 (m, 2H, N-CH₂), 3.37 (p, J = 2.9 Hz, 1H, CH), 7.12–7.22 (m, 2H, 2xCH_{Ar}), 7.45–7.56 (m, 3H, 3xCH_{Ar}), 8.47 (dd, J = 1.7, 8.0 Hz, 2H, 2xCH_{Ar}), 8.57 (dd, J = 5.9, 9.3 Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 27.8 (2xCH₂), 33.7 (CH), 48.9 (2xN-CH₂), 115.3 (CH_{Ar}), 115.5 (CH_{Ar}), 128.3 (2xCH_{Ar}), 130.1 (CH_{Ar}), 130.2 (2xCH_{Ar}), 130.3 (CH_{Ar}), 130.4 (CH_{Ar}), 134.6 (d, J = 2.9 Hz, C_q), 136.1 (C_q), 139.2 (C_q), 154.9 (C_q), 160.19 (C_q), 164.5 (d, J = 249.5 Hz, C_{Ar}-F), 175.3 (C_q). ¹⁹F NMR (376 MHz, CDCl₃) δ : -111.46. HRMS (EI/MS): m/z calculated for C₂₁H₁₉FN₃: 332.1558 [M + H]⁺; found: 332.1563.

4-(4-Phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-yl)benzonitrile (48). Compound 48 was obtained according to general procedure D using 4-cyanophenylboronic acid (236 mg, 1.60 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 48 (224 mg, 82%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.22. M_p : 202–204 °C. IR (ATR diamond, cm⁻¹) ν : 2956, 2922, 2227, 1549, 1389, 771, 693, 622, 541. ¹H NMR (400 MHz, CDCl₃) δ : 1.74–1.87 (m, 2H, CH₂), 2.05–2.16 (m, 2H, CH₂), 2.71–2.83 (m, 2H, N-CH₂), 3.23–3.34 (m, 2H, N-CH₂), 3.40 (p, J = 2.9 Hz, 1H, CH), 7.47–7.57 (m, 3H, 3xCH_{Ar}), 7.79 (d, J = 8.5 Hz, 2H, 2xCH_{Ar}), 8.43–8.54 (m, 2H, 2xCH_{Ar}), 8.69 (d, J = 8.5 Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 27.8 (2xCH₂), 33.7 (CH), 48.8 (2xN-CH₂), 113.5 (C_q), 119.1 (C_q), 128.4 (2xCH_{Ar}), 128.8 (2xCH_{Ar}), 130.2 (2xCH_{Ar}), 130.4 (2xCH_{Ar}), 132.4 (2xCH_{Ar}), 135.8 (C_q), 140.3 (C_q), 142.5 (C_q), 155.1 (C_q), 159.1 (C_q), 175.7 (C_q). HRMS (EI/MS): m/z calculated for C₂₂H₁₉N₄: 339.1604 [M + H]⁺; found: 339.1608.

4-Phenyl-2-(4-(trifluoromethyl)phenyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (49). Compound 49 was obtained according to general procedure D using 4-(trifluoromethyl)phenylboronic acid (303 mg, 1.60 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 49 (222 mg, 72%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.40. M_p : 166–168 °C. IR (ATR diamond, cm⁻¹) ν : 2953, 1552, 1389, 1320, 1116, 1061, 774, 690. ¹H NMR (400 MHz, CDCl₃) δ : 1.76–1.89 (m, 2H, CH₂), 2.04–2.16 (m, 2H, CH₂), 2.78 (td, J = 5.1, 11.7 Hz, 2H, N-CH₂), 3.23–3.34 (m, 2H, N-CH₂), 3.41 (p, J = 3.2 Hz, 1H, CH), 7.45–7.58 (m, 3H, 3xCH_{Ar}), 7.75 (d, J = 8.1 Hz, 2H, 2xCH_{Ar}), 8.50 (dt, J = 1.6, 7.5 Hz, 2H, 2xCH_{Ar}), 8.69 (d, J = 8.0 Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 27.8 (2xCH₂), 33.7 (CH), 48.8 (2xN-CH₂), 124.4 (d, J = 272.2 Hz, C_q-CF₃), 125.5 (q, J = 3.8 Hz, 2xCH_{Ar}), 128.3 (2xCH_{Ar}), 128.6 (2xCH_{Ar}), 130.2

(2xCH_{Ar}), 130.3 (CH_{Ar}), 131.8 (d, J = 32.2 Hz, CF₃), 135.9 (C_q), 140.0 (C_q), 141.7 (d, J = 1.7 Hz, C_q), 155.0 (C_q), 159.6 (C_q), 175.6 (C_q). ¹⁹F NMR (376 MHz, CDCl₃) δ : -62.59. HRMS (EI/MS): m/z calculated for C₂₂H₁₉F₃N₃: 382.1526 [M + H]⁺; found: 382.1525.

2-(4-Nitrophenyl)-4-phenyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (50). Compound 50 was obtained according to general procedure D using 4-nitrophenylboronic acid (268 mg, 1.60 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 50 (206 mg, 76%) was obtained as an orange solid. Rf (PE/EA: 90/10): 0.40. M_p : 191–193 °C. IR (ATR diamond, cm⁻¹) ν : 2925, 2872, 1555, 1519, 1388, 1350, 839, 688. ¹H NMR (400 MHz, CDCl₃) δ : 1.75–1.88 (m, 2H, CH₂), 2.06–2.18 (m, 2H, CH₂), 2.72–2.84 (m, 2H, N-CH₂), 3.24–3.35 (m, 2H, N-CH₂), 3.41 (p, J = 2.8 Hz, 1H, CH), 7.47–7.58 (m, 3H, 3xCH_{Ar}), 8.34 (dt, J = 2.0, 9.0 Hz, 2H, 2xCH_{Ar}), 8.44–8.54 (m, 2H, 2xCH_{Ar}), 8.75 (dt, J = 2.3, 9.0 Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 27.8 (2xCH₂), 33.7 (CH), 48.8 (2xN-CH₂), 123.8 (2xCH_{Ar}), 128.4 (2xCH_{Ar}), 129.2 (2xCH_{Ar}), 130.2 (2xCH_{Ar}), 130.4 (CH_{Ar}), 135.7 (C_q), 140.4 (C_q), 144.2 (C_q), 149.1 (C_q), 155.2 (C_q), 158.8 (C_q), 175.8 (C_q). HRMS (EI/MS): m/z calculated for C₂₁H₁₉N₄O₂: 359.1503 [M + H]⁺; found: 359.1506.

4-Phenyl-2-(thiophen-3-yl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (51). Compound 51 was obtained according to general procedure D using 3-thienylboronic acid (208 mg, 1.62 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), 51 (195 mg, 77%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.19. M_p : 189–191 °C. IR (ATR diamond, cm⁻¹) ν : 2956, 2867, 1553, 1386, 1342, 819, 689, 623. ¹H NMR (400 MHz, CDCl₃) δ : 1.75–1.86 (m, 2H, CH₂), 2.00–2.13 (m, 2H, CH₂), 2.76 (td, J = 5.5, 12.2 Hz, 2H, N-CH₂), 3.19–3.31 (m, 2H, N-CH₂), 3.35 (p, J = 3.3 Hz, 1H, CH), 7.38 (t, J = 3.7 Hz, 1H, CH_{Ar}), 7.42–7.55 (m, 3H, 3xCH_{Ar}), 8.00 (d, J = 5.0 Hz, 1H, CH_{Ar}), 8.31–8.36 (m, 1H, CH_{Ar}), 8.45 (d, J = 7.9 Hz, 2H, 2xCH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 27.8 (2xCH₂), 33.6 (CH), 48.9 (2xN-CH₂), 125.8 (CH_{Ar}), 127.3 (CH_{Ar}), 127.8 (CH_{Ar}), 128.2 (2xCH_{Ar}), 130.0 (CH_{Ar}), 130.2 (2xCH_{Ar}), 136.1 (C_q), 138.8 (C_q), 142.3 (C_q), 154.9 (C_q), 158.5 (C_q), 175.2 (C_q). HRMS (EI/MS): m/z calculated for C₁₉H₁₈N₃S: 320.1216 [M + H]⁺; found: 320.1223.

4-Phenyl-2-(pyridin-3-yl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (52). Compound 52 was obtained according to general procedure D using 3-pyridinylboronic acid (200 mg, 1.63 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 50/50), 52 (152 mg, 60%) was obtained as a white solid. Rf (PE/EA: 50/50): 0.25. M_p : 231–233 °C. IR (ATR diamond, cm⁻¹) ν : 2926, 2864, 1552, 1387, 1371, 1023, 843, 692, 620. ¹H NMR (400 MHz, CDCl₃) δ : 1.75–1.87 (m, 2H, CH₂), 2.02–2.15 (m, 2H, CH₂), 2.77 (td, J = 5.1, 11.6 Hz, 2H, N-CH₂), 3.22–3.33 (m, 2H, N-CH₂), 3.40 (p, J = 3.1 Hz, 1H, CH), 7.42 (dd, J = 4.8, 8.0 Hz, 1H, CH_{Ar}), 7.45–7.56 (m, 3H, 3xCH_{Ar}), 8.50 (d, J = 7.6 Hz, 2H, 2xCH_{Ar}), 8.70 (d, J = 4.8 Hz, 1H, CH_{Ar}), 8.80 (d, J = 7.8 Hz, 1H, CH_{Ar}), 9.76 (s, 1H, CH_{Ar}). ¹³C NMR (101 MHz, CDCl₃) δ : 27.8 (2xCH₂), 33.6 (CH), 48.8 (2xN-CH₂), 123.3 (CH_{Ar}), 128.3 (2xCH_{Ar}), 130.2 (2xCH_{Ar}), 130.3 (CH_{Ar}), 133.8 (C_q), 135.5 (CH_{Ar}), 135.9 (C_q), 139.9 (C_q), 150.1 (CH_{Ar}), 151.0 (CH_{Ar}), 155.0 (C_q), 159.2 (C_q), 175.6 (C_q). HRMS (EI/MS): m/z calculated for C₂₀H₁₉N₄: 315.1604 [M + H]⁺; found: 315.1602.



2,4-Di-p-tolyl-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (53). Compound **53** was obtained according to general procedure **D** using **9** (215 mg, 0.80 mmol, 1.0 eq.) and *p*-tolylboronic acid (215 mg, 1.58 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **53** (101 mg, 37%) was obtained as a beige solid. Rf (PE/EA: 90/10): 0.34. M_p : 193–195 °C. IR (ATR diamond, cm^{-1}): 2965, 2934, 2869, 1547, 1387, 1179, 812, 803, 744. ^1H NMR (400 MHz, CDCl_3) δ : 1.74–1.87 (m, 2H, CH_2), 2.00–2.12 (m, 2H, CH_2), 2.43 (s, 6H, $2\times\text{CH}_3$), 2.70–2.83 (m, 2H, N- CH_2), 3.19–3.31 (m, 2H, N- CH_2), 3.37 (p, $J = 2.9$ Hz, 1H, CH), 7.31 (dd, $J = 5.9, 8.0$ Hz, 4H, $4\times\text{CH}_{\text{Ar}}$), 8.36–8.42 (m, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.42–8.48 (m, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.6 (CH_3), 21.6 (CH_3), 27.9 ($2\times\text{CH}_2$), 33.7 (CH), 48.9 ($2\times\text{N-CH}_2$), 128.3 ($2\times\text{CH}_{\text{Ar}}$), 129.0 ($2\times\text{CH}_{\text{Ar}}$), 129.3 ($2\times\text{CH}_{\text{Ar}}$), 130.1 ($2\times\text{CH}_{\text{Ar}}$), 133.6 (C_q), 135.7 (C_q), 138.8 (C_q), 140.1 (C_q), 140.2 (C_q), 154.8 (C_q), 161.1 (C_q), 174.8 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{23}\text{H}_{24}\text{N}_3$: 342.1965 [$\text{M} + \text{H}$] $^+$; found: 342.1962.

4-(4-(p-Tolyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-yl)benzotrile (54). Compound **54** was obtained according to general procedure **D** using **9** (215 mg, 0.80 mmol, 1.0 eq.) and 4-cyanophenylboronic acid (238 mg, 1.62 mmol, 2.0 eq.). After purification by silica gel flash chromatography (DCM/PE, 60/40 to 80/20), **54** (148 mg, 52%) was obtained as a beige solid. Rf (DCM/PE: 80/20): 0.55. M_p : 236–238 °C. IR (ATR diamond, cm^{-1}): 2940, 2227, 1548, 1387, 1167, 816, 612. ^1H NMR (400 MHz, CDCl_3) δ : 1.73–1.86 (m, 2H, CH_2), 2.03–2.15 (m, 2H, CH_2), 2.44 (s, 3H, CH_3), 2.70–2.82 (m, 2H, N- CH_2), 3.22–3.33 (m, 2H, N- CH_2), 3.38 (p, $J = 2.8$ Hz, 1H, CH), 7.33 (d, $J = 8.0$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.78 (d, $J = 8.6$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.39 (d, $J = 8.3$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.68 (d, $J = 8.5$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.6 (CH_3), 27.8 ($2\times\text{CH}_2$), 33.7 (CH), 48.8 ($2\times\text{N-CH}_2$), 113.4 (C_q), 119.1 (C_q), 128.8 ($2\times\text{CH}_{\text{Ar}}$), 129.1 ($2\times\text{CH}_{\text{Ar}}$), 130.2 ($2\times\text{CH}_{\text{Ar}}$), 132.4 ($2\times\text{CH}_{\text{Ar}}$), 133.0 (C_q), 140.0 (C_q), 140.7 (C_q), 142.6 (C_q), 155.2 (C_q), 159.0 (C_q), 175.5 (C_q). HRMS (EI/MS): m/z calculated for $\text{C}_{23}\text{H}_{21}\text{N}_4$: 353.1761 [$\text{M} + \text{H}$] $^+$; found: 353.1759.

4-(4-Fluorophenyl)-2-(p-tolyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidine (55). Compound **55** was obtained according to general procedure **D** using **10** (110 mg, 0.40 mmol, 1.0 eq.) and *p*-tolylboronic acid (109 mg, 0.80 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **55** (63 mg, 45%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.49. M_p : 164–166 °C. IR (ATR diamond, cm^{-1}): 2926, 2869, 1550, 1505, 1386, 1220, 1155, 819. ^1H NMR (400 MHz, CDCl_3) δ : 1.74–1.87 (m, 2H, CH_2), 2.01–2.13 (m, 2H, CH_2), 2.43 (s, 3H, CH_3), 2.70–2.82 (m, 2H, N- CH_2), 3.19–3.31 (m, 2H, N- CH_2), 3.37 (p, $J = 2.9$ Hz, 1H, CH), 7.18 (t, $J = 8.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 7.30 (d, $J = 8.0$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.44 (d, $J = 8.2$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$), 8.59 (dd, $J = 5.8, 8.8$ Hz, 2H, $2\times\text{CH}_{\text{Ar}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 21.6 (CH_3), 27.8 ($2\times\text{CH}_2$), 33.6 (CH), 48.8 ($2\times\text{N-CH}_2$), 115.1 (CH_{Ar}), 115.3 (CH_{Ar}), 128.2 ($2\times\text{CH}_{\text{Ar}}$), 129.3 ($2\times\text{CH}_{\text{Ar}}$), 132.3 (CH_{Ar}), 132.4 (CH_{Ar}), 132.5 (d, $J = 3.2$ Hz, C_q), 135.5 (C_q), 138.7 (C_q), 140.4 (C_q), 153.4 (C_q), 161.1 (C_q), 164.1 (d, $J = 250.5$ Hz, $\text{C}_q\text{-F}$), 175.2 (C_q). ^{19}F NMR (376 MHz, CDCl_3) δ : –110.90. HRMS (EI/MS): m/z calculated for $\text{C}_{22}\text{H}_{21}\text{FN}_3$: 346.1714 [$\text{M} + \text{H}$] $^+$; found: 346.1710.

4-(4-(4-Fluorophenyl)-7,8-dihydro-6H-5,8-ethanopyrido[3,2-d]pyrimidin-2-yl)benzotrile (56). Compound **56** was obtained

according to general procedure **D** using **10** (109 mg, 0.40 mmol, 1.0 eq.) and 4-cyanophenylboronic acid (118 mg, 0.80 mmol, 2.0 eq.). After purification by silica gel flash chromatography (PE/EA, 90/10), **56** (97 mg, 68%) was obtained as a white solid. Rf (PE/EA: 90/10): 0.20. M_p : 237–239 °C. IR (ATR diamond, cm^{-1}): 2950, 2917, 2221, 1602, 1544, 1504, 1382, 1157, 824, 568. ^1H NMR (400 MHz, CDCl_3) δ : 1.74–1.86 (m, 2H, CH_2), 2.05–2.17 (m, 2H, CH_2), 2.70–2.81 (m, 2H, N- CH_2), 3.22–3.34 (m, 2H, N- CH_2), 3.39 (p, $J = 2.8$ Hz, 1H, CH), 7.19 (t, $J = 8.7$ Hz, 2H, $2\times\text{CH}_{\text{Ar-F}}$), 7.79 (d, $J = 8.5$ Hz, 2H, $2\times\text{CH}_{\text{Ar-CN}}$), 8.60 (dd, $J = 5.6, 8.9$ Hz, 2H, $2\times\text{CH}_{\text{Ar-F}}$), 8.67 (d, $J = 8.5$ Hz, 2H, $2\times\text{CH}_{\text{Ar-CN}}$). ^{13}C NMR (101 MHz, CDCl_3) δ : 27.7 ($2\times\text{CH}_2$), 33.7 (CH), 48.7 ($2\times\text{N-CH}_2$), 113.6 (C_q), 115.3 ($\text{CH}_{\text{Ar-F}}$), 115.5 ($\text{CH}_{\text{Ar-F}}$), 119.1 (C_q), 128.8 ($2\times\text{CH}_{\text{Ar-CN}}$), 131.9 (d, $J = 3.1$ Hz, C_q), 132.4 ($2\times\text{CH}_{\text{Ar-CN}}$), 132.4 ($\text{CH}_{\text{Ar-F}}$), 132.5 ($\text{CH}_{\text{Ar-F}}$), 139.9 (C_q), 142.4 (C_q), 153.8 (C_q), 159.1 (C_q), 164.3 (d, $J = 251.4$ Hz, $\text{C}_q\text{-F}$), 175.8 (C_q). ^{19}F NMR (376 MHz, CDCl_3) δ : –110.06. HRMS (EI/MS): m/z calculated for $\text{C}_{22}\text{H}_{18}\text{FN}_4$: 357.1510 [$\text{M} + \text{H}$] $^+$; found: 357.1505.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgements

The authors would like to thank the Région Centre Val de Loire (RTR Motivhealth, APR-IR FLOWSYN and INFLUX), FEDER under projects Valbiocosm FEDER-FSE 2017-EX003202, CHembio FEDER-FSE 2014-2020-EX003677, Techsab FEDER-FSE 2014-2020-EX011313 and Mystic FEDER-FSE 2014-2020-EX003242; the SFR neuroimagerie (SFR FED 4224), the GDR Synth_Flux, the Labex programs SYNORG (ANR-11-LABX-0029) and IRON (ANR-11-LABX-0018-01), the Ligue contre le Cancer du Grand Ouest (comités des Deux Sèvres, du Finistère, de l'Île et Villaine, du Loir et Cher, de Loire Atlantique, du Loiret, de la Vienne) for their financial support.

Notes and references

- 1 E. J. Llanos, W. Leal, D. H. Luu, J. Jost, P. F. Stadler and G. Restrepo, *Proc. Natl. Acad. Sci.*, 2019, **116**, 12660–12665.
- 2 J.-L. Reymond, R. van Deursen, L. C. Blum and L. Ruddigkeit, *MedChemComm*, 2010, **1**, 30–38.
- 3 K. K. Duncan, D. D. Rudnicki, C. P. Austin and D. A. Tagle, *Front. Robot. AI*, 2020, **6**, 1–6.
- 4 M. Aldeghi, S. Malhotra, D. L. Selwood and A. W. E. Chan, *Chem. Biol. Drug Des.*, 2014, **83**, 450–461.
- 5 C. Cabrele and O. Reiser, *J. Org. Chem.*, 2016, **81**, 10109–10125.
- 6 E. Vitaku, D. T. Smith and J. T. Njardarson, *J. Med. Chem.*, 2014, **57**, 10257–10274.
- 7 R. D. Taylor, M. MacCoss and A. D. G. Lawson, *J. Med. Chem.*, 2014, **57**, 5845–5859.
- 8 D. C. Blakemore, L. Castro, I. Churcher, D. C. Rees, A. W. Thomas, D. M. Wilson and A. Wood, *Nat. Chem.*, 2018, **10**, 383–394.



- 9 F. Lovering, J. Bikker and C. Humblet, *J. Med. Chem.*, 2009, **52**, 6752–6756.
- 10 F. Lovering, *MedChemComm*, 2013, **4**, 515–519.
- 11 T. J. Ritchie and S. J. F. Macdonald, *Drug Discovery Today*, 2009, **14**, 1011–1020.
- 12 K. C. Bharadwaj, T. Gupta and R. M. Singh, in *Synthesis of Medicinal Agents from Plants*, ed. A. Tewari and S. Tiwari, Elsevier, 2018, pp. 205–227, DOI: 10.1016/B978-0-08-102071-5.00009-X.
- 13 J. Achan, A. O. Talisuna, A. Erhart, A. Yeka, J. K. Tibenderana, F. N. Baliraine, P. J. Rosenthal and U. D'Alessandro, *Malar. J.*, 2011, **10**, 144.
- 14 S. Tsukagoshi, *Cancer Chemother.*, 1999, **26**, 1001–1008.
- 15 N. Ramírez Chanona, B. E. del Rio Navarro and J. Pérez Martín, *Rev. Alerg. Mex.*, 2005, **52**, 221–225.
- 16 H. Sakamoto, N. Yokoyama, S. Kohno and K. Ohata, *Jpn. J. Pharmacol.*, 1984, **36**, 455–460.
- 17 S. Kobayashi, K. Ikeda, M. Suzuki, T. Yamada and K. Miyata, *Jpn. J. Pharmacol.*, 2001, **86**, 281–288.
- 18 S. France, D. J. Guerin, S. J. Miller and T. Lectka, *Chem. Rev.*, 2003, **103**, 2985–3012.
- 19 S.-K. Tian, Y. Chen, J. Hang, L. Tang, P. McDaid and L. Deng, *Acc. Chem. Res.*, 2004, **37**, 621–631.
- 20 M. J. Gaunt and C. C. C. Johansson, *Chem. Rev.*, 2007, **107**, 5596–5605.
- 21 T. Ooi and K. Maruoka, *Angew. Chem., Int. Ed.*, 2007, **46**, 4222–4266.
- 22 C. E. Song, in *Cinchona Alkaloids in Synthesis and Catalysis*, 2009, pp. 1–10, DOI: 10.1002/9783527628179.ch1.
- 23 P. J. Boratynski, M. Zielińska-Błajet and J. Skarzewski, in *Alkaloids Chem. Biol.*, ed. H.-J. Knölker, Academic Press, 2019, vol. 82, pp. 29–145.
- 24 R. Madhav, *Synthesis*, 1982, **1982**, 27.
- 25 Y. Besidsky, K. Luthman, A. Claesson, C. J. Fowler, I. Csöregyh and U. Hacksell, *J. Chem. Soc., Perkin Trans. 1*, 1995, 465–474, DOI: 10.1039/p19950000465.
- 26 G. W. V. Cave and C. L. Raston, *Tetrahedron Lett.*, 2005, **46**, 2361–2363.
- 27 W. S. Hamama, O. M. A. El-Magid and H. H. Zoorob, *J. Heterocycl. Chem.*, 2006, **43**, 1397–1420.
- 28 A. Ejjoummany, R. Belaroussi, A. El Hakmaoui, M. Akssira, G. Guillaumet, F. Buron and S. Routier, *Molecules*, 2018, **23**, 2740.
- 29 T. Saurat, F. Buron, N. Rodrigues, M.-L. de Tauzia, L. Colliandre, S. Bourg, P. Bonnet, G. Guillaumet, M. Akssira, A. Corlu, C. Guillouzo, P. Berthier, P. Rio, M.-L. Jourdan, H. Benedetti and S. Routier, *J. Med. Chem.*, 2014, **57**, 613–631.
- 30 F. Buron, J. Y. Merour, M. Akssira, G. Guillaumet and S. Routier, *Eur. J. Med. Chem.*, 2015, **95**, 76–95.
- 31 R. Belaroussi, A. Ejjoummany, A. El Hakmaoui, M. Akssira, G. Guillaumet and S. Routier, *RSC Adv.*, 2018, **8**, 732–741.
- 32 WO2019231942A1, 2019.
- 33 G. Lavecchia, S. Berteina-Raboin and G. Guillaumet, *Tetrahedron Lett.*, 2005, **46**, 5851–5855.
- 34 P. A. Solov'yev and A. D. Shutalev, *Chem. Heterocycl. Compd.*, 2009, **45**, 809.
- 35 F.-A. Kang, Z. Sui and W. V. Murray, *Eur. J. Org. Chem.*, 2009, **2009**, 461–479.
- 36 R. Belaroussi, A. El Hakmaoui, M. Akssira, G. Guillaumet and S. Routier, *Eur. J. Org. Chem.*, 2016, **2016**, 3550–3558.
- 37 B. Jismy, G. Guillaumet, M. Akssira, A. Tikad and M. Abarbri, *RSC Adv.*, 2021, **11**, 1287–1302.
- 38 B. Jismy, A. Tikad, M. Akssira, G. Guillaumet and M. Abarbri, *Molecules*, 2020, **25**, 2062.
- 39 B. Jismy, H. Allouchi, G. Guillaumet, M. Akssira and M. Abarbri, *Synthesis*, 2018, **50**, 1675–1686.
- 40 C. Guo-Jun, H. Jie, G. Lian-Xun and H. Fu-She, *Chem.-Eur. J.*, 2011, **17**, 4038–4042.
- 41 F.-A. Kang, Z. Sui and W. V. Murray, *J. Am. Chem. Soc.*, 2008, **130**, 11300–11302.

