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Plant Coumarins: VII.* Amination of Oreoselone Trifluoromethanesulfonate

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Abstract—Amination of oreoselone trifluoromethanesulfonate with N-substituted piperazines, anabasine, aniline derivatives, quinolin- and isoquinolinamines, and amino acids of the penicillin and cephalosporin series in the presence of palladium complexes gave the corresponding N-substituted 3-aminofurocoumarins. The yield of the amination products depended on the catalytic system and base used.

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Various amino- and amido-substituted coumarins produced by *Streptomyces sp.* attract attention due to their valuable biological activity [2]. Natural and synthetic aminocoumarins are promising from the viewpoint of medicinal chemistry for the design of new antibiotics and antitumor and antiviral agents [3]. Introduction of a nitrogen-containing functional group into psoralen molecule changes its phototoxicity and in some cases enhances photoantiproliferative activity [4]. Furthermore, extensive search for selective monoaminooxidase (MAO-A) inhibitors and antidepressants is performed in the series of amino-substituted furocoumarins [5, 6].

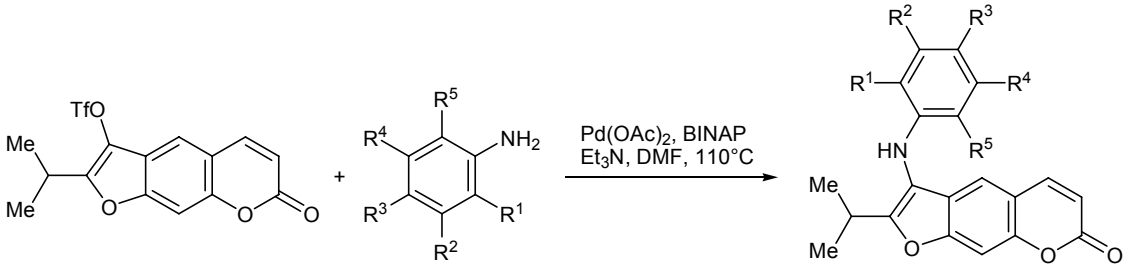
Classical procedures for the synthesis of aminocoumarins are based on addition–elimination reactions of 4-halo- or 4-trifluoromethyl-substituted coumarins with aliphatic or aromatic amines [7] and reduction of 3-nitrocoumarins into 3-aminocoumarins with subsequent functionalization at the nitrogen atom [5, 8]. Although considerable attention has been given in the recent time to amination and amidation of various halogen derivatives and trifluoromethanesulfonates, catalyzed by transition metals [9], only a few examples of preparation of nitrogen-containing coumarin derivatives via the above reactions have been reported. Wang et al. [10] described the synthesis of 3-amino-4-sulfanylcoumarins by palladium-catalyzed amination of 3-bromo-4-tosyloxycoumarins; N-substituted 3-aminocoumarins were synthesized by Audisio et al. [11] according to Buchwald–Hartwig; and Ganina et al. [12] reported on palladium-catalyzed reactions of 4-trifluoromethylsulfonyloxy-substituted coumarins with amides and NH-heterocycles. As applied to furocoumarins, only amination of 2-(1,3-dibromopropan-2-ylidene)oreoselone was reported [13]. This compound reacted with various amines and amino acid derivatives in the presence of palladium complexes to produce 2-(1,3-diaminopropan-2-ylidene)-substituted furocoumarins, whereas its amination with di- and polyamines afforded macrocyclic compounds containing furocoumarin fragments. Amination of furocoumarins at the 3-position was not studied.

The present work was aimed at synthesizing furocoumarins having a substituted amino group on C^3 via palladium-catalyzed amination of oreoselone trifluoromethanesulfonate (**I**). Compound **I** is readily prepared in two steps from an accessible plant furocoumarin, peucedanin, by hydrolysis with a solution of hydrochloric acid in methanol and subsequent treatment with trifluoroacetic anhydride [1].

First of all, we examined amination of oreoselone trifluoromethanesulfonate (**I**) with substituted anilines **IIa**–**III** (Scheme 1), specifically with those containing piperidino (**IIb**, **III**), fluoro (**IId**–**IIh**), and trifluoromethyl groups (**IIe**–**III**). Furocoumarins modified with a 2-piperidinoaniline fragment attract interest taking into account that some furfurylpiperidinoaniline derivatives were found to act as selective cFMS tyrosine kinase inhibitors (potential anti-inflammatory agents)

* For communication VI, see [1].

Scheme 1.



I **IIa**, **IIc–III** **IIIa**, **IIIc–IIII**

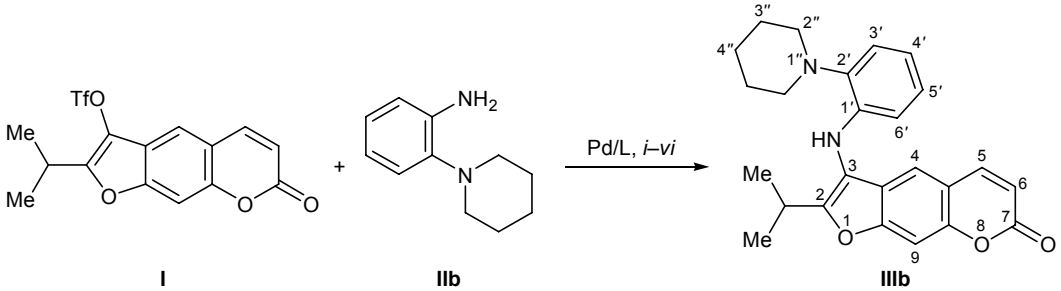
$R^1 = R^2 = R^3 = R^4 = R^5 = H$ (**a**); $R^1 = R^3 = R^4 = R^5 = H$, $R^2 = Cl$ (**c**); $R^1 = R^3 = R^4 = R^5 = H$, $R^2 = F$ (**d**); $R^1 = F$, $R^2 = R^3 = R^4 = H$, $R^5 = CF_3$ (**e**); $R^1 = CF_3$, $R^2 = R^3 = R^5 = H$, $R^4 = F$ (**f**); $R^1 = CF_3$, $R^2 = R^4 = R^5 = H$, $R^3 = F$ (g); $R^1 = R^4 = R^5 = H$, $R^2 = CF_3$, $R^3 = F$ (**h**); $R^1 = R^4 = R^5 = H$, $R^2 = CF_3$, $R^3 = Me$ (**i**); $R^1 = R^4 = R^5 = H$, $R^2 = CF_3$, $R^3 = MeS$ (**j**); R^1 = morpholino, $R^2 = R^3 = R^5 = H$, $R^4 = CF_3$ (**k**); R^1 = piperidino, $R^2 = R^3 = R^4 = H$, $R^5 = CF_3$ (**l**).

[14] and that heterocyclic anilinopiperidine derivatives were reported to activate adrenoreceptors [15]. Modification of furocoumarins with fluorine-containing anilines was performed in view of important role of fluorinated substituents in medicinal chemistry (as a rule, replacement of hydrogen by fluorine changes the selectivity and affinity for various receptors and enhances biological activity) [16].

The reaction conditions were optimized using the amination of oreoselone trifluoromethanesulfonate (**I**) with 2-piperidinoaniline (**IIb**) as model reaction (Scheme 2). Palladium(II) acetate was used as source of palladium, and BINAP, (*o*-Tol)$_3$P, Xantphos, and *t*-Bu$_3$P were tried as ligands. When the reaction was carried out in DMF in the presence of 1.3 equiv of triethylamine (115°C, 7 h) the yield of 3-(2-piperidinophenylamino)-7*H*-furo[3,2-*g*]chromen-7-one (**IIIb**) was 64, 58, 50, and 26%, respectively. In the latter case, 8% of unchanged trifluoromethanesulfonate **I** was recovered from the reaction mixture. Replacement of DMF by acetonitrile and lowering the temperature (85°C, 10 h) did not result in increased yield of **IIIb**. The amination of **I** using a different catalytic system, Pd(OAc)$_2$/BINAP (2/8 mol %), and cesium carbonate as base (solvent toluene) [17] was characterized by considerably lower yield of the target product. Thus the most efficient were Pd(OAc)$_2$/BINAP as catalytic system and triethylamine as base.

The results of amination of compound **I** with anilines **IIa–III** under the optimal conditions are collected in table. It is seen that the yield of the amination product depends on the substituents in the aromatic ring of **II**. The highest yield (74%, **IIIj**) was obtained in the reaction of **I** with aniline **IIj** having an electron-donor methylsulfanyl group in the *para*-position. In this case the reaction was complete in 4 h, whereas reactions with other anilines required 5 to 7 h. Fairly high yields of the amination products were observed in the reactions with unsubstituted aniline (**IIa**), 2-piperidinoaniline (**IIb**), and 5-methyl-3-trifluoromethylaniline (**IIi**). The presence of electron-withdrawing substituents in the *ortho* and *meta* positions of the aniline molecule reduced the yield of the amination products (cf. the data for anilines **IIb** and **III**). The lowest yields were obtained in the amination of oreoselone trifluoromethanesulfonate (**I**) with anilines **IIe** and **IIg**, each

Scheme 2.



I **IIb** **IIIb**

i: Pd(OAc)$_2$, BINAP, Et$_3$N, DMF; *ii*: Pd(OAc)$_2$, (*o*-Tol)$_3$P, Et$_3$N, DMF; *iii*: Pd(OAc)$_2$, (*t*-Bu)$_3$P, Et$_3$N, DMF; *iv*: Pd(OAc)$_2$, BINAP, Et$_3$N, MeCN; *v*: Pd(OAc)$_2$, BINAP, Cs_2CO_3, toluene; *vi*: Pd(OAc)$_2$, Xantphos, Et$_3$N, DMF.

Yields of 3-arylaminofurocoumarins **IIIa** and **IIIc**–**IIIl** in the amination of oreoselone trifluoromethanesulfonate (**I**)

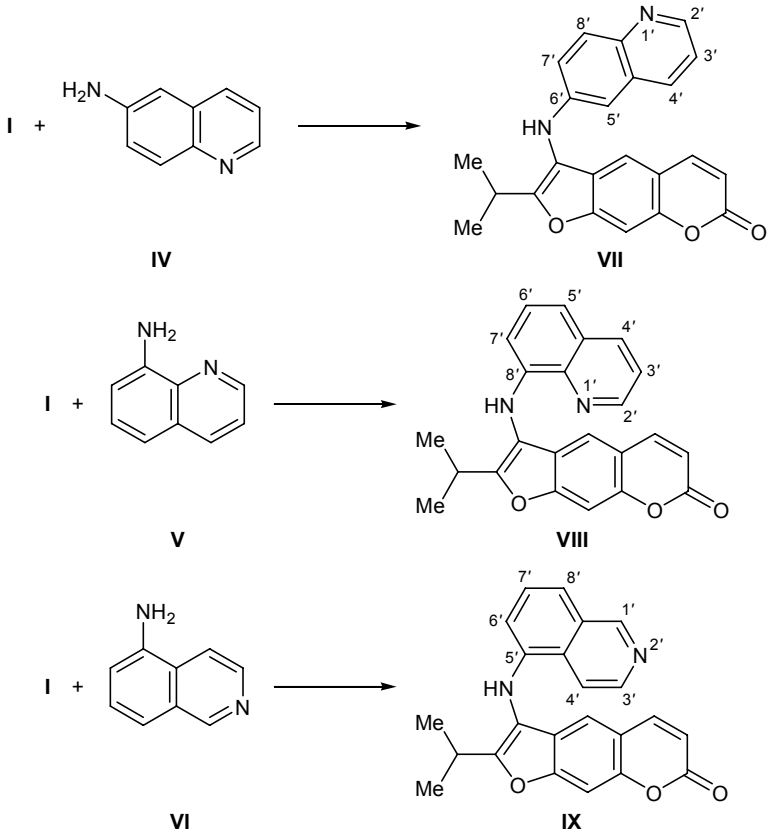
Amine	Reaction time, h	Product	Yield, %
Aniline (**IIa**)	6	**IIIa**	62
3-Chloroaniline (**IIc**)	6	**IIIc**	58
3-Fluoroaniline (**IId**)	6	**IIId**	55
2-Fluoro-6-trifluoromethylaniline (**IIe**)	7	**IIIe**	28
5-Fluoro-2-trifluoromethylaniline (**IIf**)	6	**IIIf**	37
4-Fluoro-2-trifluoromethylaniline (**IIg**)	7	**IIIg**	31
4-Fluoro-3-trifluoromethylaniline (**IIh**)	6	**IIIh**	48
4-Methyl-3-trifluoromethylaniline (**IIi**)	5	**IIIi**	66
4-Methylsulfanyl-3-trifluoromethylaniline (**IIj**)	4	**IIIj**	74
2-Morpholino-5-trifluoromethylaniline (**IIk**)	6	**IIIk**	45
2-Piperidino-6-trifluoromethylaniline (**IIl**)	6	**IIIl**	49

having two electron-withdrawing substituents in the *ortho* and *para* or *meta* positions.

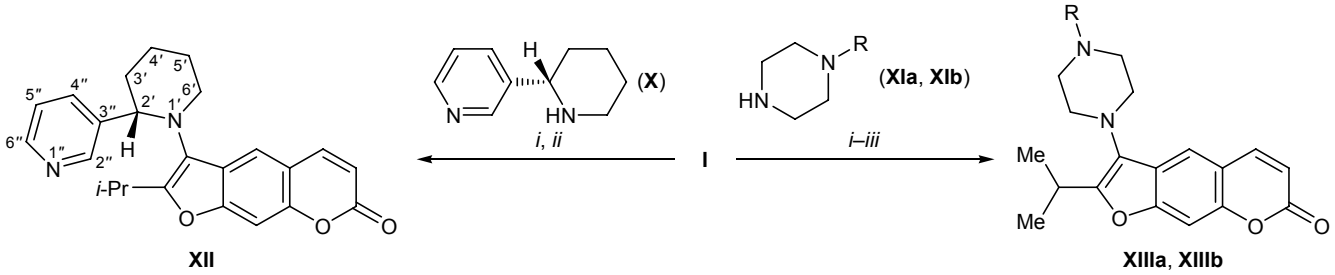
Taking into account high reactivity of aniline **IIj**, we made an attempt to obtain 3-anilinooreoselone derivative **IIIj** under classical addition–elimination conditions (heating in dioxane in the presence of a base). However, only the initial compounds were isolated after heating of a mixture of compounds **I** and **IIj** in the presence of pyridine for 6 h.

The reactions of trifluoromethanesulfonate **I** with quinolin-6-amine (**IV**), quinolin-8-amine (**V**), and isoquinolin-5-amine (**VI**) in DMF in the presence of $Pd(OAc)_2$/BINAP as catalytic system and triethylamine gave the corresponding substituted furocou-

Scheme 3.



Scheme 4.



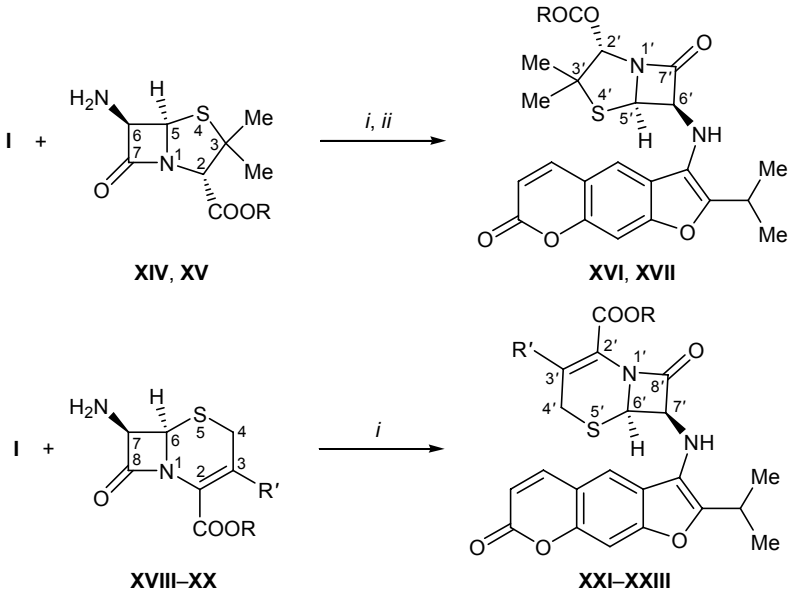
R = *t*-BuOCO (**a**), Me (**b**); *i*: $Pd(OAc)_2$, BINAP, Et_3N, DMF; *ii*: $Pd(OAc)_2$, Xantphos, Et_3N, DMF; *iii*: $Pd(OAc)_2$, *t*-Bu_3P, Et_3N, DMF.

marins **VII**–**IX** in 45, 32, and 48% yield, respectively (Scheme 3). Reduced yield in the reaction with quinolin-8-amine (**V**) should be noted. Cyclic secondary amines, in particular anabasine (**X**) and N-substituted piperazines **XIa** and **XIb** reacted with compound **I** to produce the corresponding amination products in high yield. In the reactions of **I** with alkaloid **X** in DMF in the presence of $Pd(OAc)_2$/BINAP and $Pd(OAc)_2$/Xantphos as catalytic system, compound **XII** was obtained in 68 and 53% yield, respectively.

The amination of **I** with N-Boc-protected piperazine **XIa** in the presence of $Pd(OAc)_2$/BINAP (4/8 mol %) afforded 42% of 3-(4-Boc-piperazin-1-yl)-7*H*-furo[3,2-*g*]chromen-7-one (**XIIIa**) (Scheme 4). Analogous results were obtained in the reactions of **I** with piperazines **XIa** and **XIb** carried out in the presence of $Pd(OAc)_2$/Xantphos (4/8 mol %) (yield 40–45%). The yield of the amination product did not increase when N-Boc-piperazine **XIa** was added in portions in 30 min after mixing the initial coumarin with the catalyst and base according to the recommendations given in [18]. The use of tri-*tert*-butylphosphine as ligand was also inefficient: the yield of compound **XIIIa** was 35%.

With a view to obtain analogs of lactam antibiotics containing a furocoumarin fragment, we performed amination of trifluoromethanesulfonate **I** with amines of the penam and cepham series. Combination of coumarin and β-lactam fragments in a single molecule seems to be promising taking into accounts modern trends in improvement of penicillins via conjugation with peptides, catechols, and isochromans [19, 20]. By reactions of **I** with 6-aminopenicillanic acid (**XIV**) and its methyl ester **XV** in DMF ($Pd(OAc)_2$/BINAP,

Scheme 5.



XIV, **XVI**, R = H; **XV**, **XVII**, R = Me; **XVIII**–**XXII**, R′ = $MeC(O)OCH_2$; **XVIII**, **XXI**, R = H; **XIX**, **XXII**, R = Me; **XX**, **XXIII**, R = R′ = Me; *i*: $Pd(OAc)_2$, BINAP, Et_3N, DMF; *ii*: $Pd(OAc)_2$, BINAP, $(i\text{-Pr})_2NH$, DMF.

4/8 mol %; Et_3N) we obtained 48–66% of furocoumarins **XVI** and **XVII** containing a penicillin fragment (Scheme 5). Our attempt to raise the yield of amination product **XVI** and reduce tarring in the reaction of **I** with amine **XIV** by replacing triethylamine by diisopropylamine was not successful. The amination of oreoselone trifluoromethanesulfonate **I** with 7-aminocephalosporanic acid (**XVIII**), 7-amino(deacetoxy)-cephalosporanic acid (**XIX**), and 7-amino(deacetoxy)-cephalosporanic acid methyl ester (**XX**) under analogous conditions gave compounds **XXI**–**XXIII** in 36–42% yield. The lowest yield was observed in the amination of compound **I** with 7-aminocephalosporanic acid (**XVIII**).

The structure of the synthesized compounds was determined on the basis of their spectral parameters and elemental compositions. The amination products displayed in the electronic spectra absorption bands typical of furocoumarins. In particular, the UV spectra of all compounds **IIIa**–**IIIl**, **VII**–**IX**, **XII**, **XIIIa**, **XIIIb**, **XVI**, **XVII**, and **XXI**–**XXIII** contained absorption bands with their maxima at λ 244–253, 280–295, and 333–338 nm. 3-Anilino, 3-quinolinyl, and 3-isoquinolinyl derivatives were characterized by a larger number of absorption bands and increased intensity of absorption maxima at λ 240–300 nm. For example, absorption maxima at λ 223, 228, 234, 252, 297, 308, 342, and 353 nm were observed in the UV spectrum of compound **IX**. The ^{1}H and ^{13}C NMR spectra of the amination products contained only one set of signals from the furocoumarin fragment and the corresponding substituent and were consistent with the assumed structure.

In the IR spectra of lactam derivatives **XVI**, **XXI**, **XXII**, absorption bands at 1730–1770 (β-lactam carbonyl), 1690–1720 (COOH, $COCH_3$, C^7=O), and 3460–3435, 3190, 3090, 3062 cm^{-1} (NH, OH) were present. Protons in the lactam ring of **XVI** and **XVII** (5′-H, 6′-H) and **XXI**–**XXIII** (6′-H, 7′-H) resonated in the ^{1}H NMR spectra at δ 4.52–5.15 and 4.88–5.48 ppm, respectively (^3J = 4.6–5.0 Hz).

Thus the amination of oreoselone trifluoromethanesulfonate with various amines gives N-substituted 3-aminofurocoumarin derivatives which attract interest as potential pharmacologically active compounds.

EXPERIMENTAL

The NMR spectra were recorded on Bruker AV-300 (300.13 MHz for ^{1}H and 75.47 MHz for ^{13}C), AV-400 (400.13 MHz for ^{1}H and 100.78 MHz for ^{13}C), and AV-600 spectrometers (600.30 MHz for ^{1}H and 150.96 MHz for ^{13}C). The ^{1}H and ^{13}C chemical shifts were measured relative to the residual proton signal and carbon signal of the solvent ($CHCl_3$, δ 7.24; $CDCl_3$, δ_C 76.90 ppm); the ^{19}F chemical shifts were determined relative to C_6F_6 (δ_F 0.00 ppm) as internal reference. Signal multiplicities in the ^{13}C NMR spectra were determined using *J* modulation technique. Signals in the NMR spectra of compounds **VIII**, **XVI**, **XVII**, and **XXII** were assigned on the basis of carbon–proton shift correlation experiments (COXH, COLOC). The IR spectra were obtained on a Bruker Vector-22 instrument from samples prepared as KBr pellets. The electronic absorption spectra were recorded on an HP 8453 UV-Vis spectrophotometer. The optical rotations $[\alpha]_D^{20}$ were measured at room temperature (20–23°C) on a PolAAr3005 polarimeter. The elemental compositions were determined on a Carlo Erba 1106 CHN analyzer.

The products were isolated by column chromatography on silica gel (0.035–0.070 mm, Acros Organics) or neutral aluminum oxide using chloroform or chloroform–ethanol (50:3) as eluent. The progress of reactions was monitored by TLC on Silufol UV-254 plates using chloroform or chloroform–ethanol (50:3) as eluent; spots were visualized by treatment with iodine vapor and under UV light.

The solvents (acetonitrile, dimethylformamide, toluene, dioxane) and triethylamine were distilled in a stream of argon just before use. The ligands [(*o*-Tol)$_3$P, (*R*)-(+)-BINAP, (*t*-Bu)$_3$P, Xantphos], diisopropylamine, and trifluoromethanesulfonic anhydride were commercial products (Alfa Aesar). 6-Aminopenicillanic acid methyl ester (**XV**) and 7-aminodeacetoxycephalosporanic acid methyl ester (**XX**) were synthesized according to the procedure described in [20]; the spectral parameters of compound **XV** were consistent with those given in [20]. Palladium(II) acetate was prepared as reported in [21], and oreoselone trifluoromethanesulfonate (**I**) was synthesized from peucedanin according to [1].

2-Isopropyl-3-phenylamino-7*H*-furo[3,2-*g*]chromen-7-one (IIIa). Oreoselone trifluoromethanesulfonate (**I**), 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous dimethylformamide, 93 mg (1 mmol) of aniline (**IIa**), 2.2 mg (2 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (0.65 mmol) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 6 h at 115°C until initial compound **I** disappeared

(TLC) and evaporated. The residue was subjected to column chromatography on silica gel to isolate 105 mg (62%) of compound **IIIa** as a yellow oily substance. IR spectrum, ν, cm^{-1}: 3360, 3090, 3061, 2978, 2928, 2880, 2854, 1732, 1627, 1578, 1452, 1429, 1350, 1321, 1288, 1248, 1211, 1140, 1072, 1047, 959, 901, 868, 824, 746, 696. UV spectrum (EtOH), λ_{max}, nm (log ε): 201 (4.29), 250 (4.30), 285 (3.84), 337 (3.72). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.26 d [6H, $(CH_3)_2CH$, J = 7 Hz], 3.09 m [1H, $CH(CH_3)_2$], 3.88 br.s (1H, NH), 6.32 d (1H, 6-H, J = 9.7 Hz), 6.87 t (1H, 4′-H), 7.19 s (1H, 9-H), 7.27 m (2H, 2′-H, 6′-H), 7.36 m (2H, 3′-H, 5′-H), 7.50 s (1H, 4-H), 7.75 d (1H, 5-H, J = 9.7 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.72 q [$(CH_3)_2CH$], 23.40 d [$CH(CH_3)_2$], 100.40 d (C^9), 114.35 d (C^6), 114.54 d (C^{4a}), 115.33 s (C^{3a}), 121.79 d (C^4), 125.59 d ($C^{2'}$, $C^{6'}$), 126.10 d ($C^{4'}$), 127.44 d ($C^{3'}$, $C^{5'}$), 136.11 d ($C^{1'}$), 143.26 d (C^2), 144.55 d (C^5), 151.26 s and 159.13 s (C^{8a}, C^{9a}), 161.24 s (C^7). Found, %: C 74.37; H 6.12; N 6.92. $C_{25}H_{26}N_2O_3$. Calculated, %: C 74.60; H 6.51; N 6.96.

2-Isopropyl-3-(2-piperidinophenylamino)-7*H*-furo[3,2-*g*]chromen-7-one (IIIb). *a*. Oreoselone trifluoromethanesulfonate (**I**), 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous dimethylformamide, 176 mg (1 mmol) of 2-piperidinoaniline (**IIb**), 2.2 mg (2 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (0.65 mmol) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 6 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel, and compound **IIIb** was precipitated from the eluate by addition of diethyl ether. Yield 128 mg (64%).

b. Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 176 mg (1 mmol) of aniline **IIb**, 2.2 mg (2 mol %) of palladium(II) acetate, 34 mg (8 mol %) of tris(*o*-tolyl)phosphine, and 0.07 ml (0.65 mmol) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 7 h at 115°C until the initial compound disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel to isolate 116 mg (58%) of compound **IIIb**.

c. Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 176 mg (1 mmol) of aniline **IIb**, 2.2 mg (2 mol %) of palladium(II) acetate, 10 mg (8 mol %) of tris(*tert*-butyl)phosphine, and 0.07 ml (0.65 mmol) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 7 h at 115°C until the initial compound disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel to isolate (in succession) 52 mg (26%) of compound **IIIb** and 15 mg (8%) of initial trifluoromethanesulfonate **I**.

d. Compound **I**, 200 mg (0.5 mmol), was dissolved in 6 ml of anhydrous acetonitrile, 176 mg (1 mmol) of aniline **IIb**, 2.2 mg (2 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (0.65 mmol) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 10 h at 85°C and evaporated. The residue was subjected to column chromatography on silica gel to isolate (in succession) 48 mg (24%) of compound **IIIb** and 28 mg (14%) of initial trifluoromethanesulfonate **I**.

e. Compound **I**, 200 mg (0.5 mmol), was dissolved in 6 ml of anhydrous toluene, 176 mg (mmol) of aniline **IIb**, 325 mg (1 mmol) of cesium carbonate, 2.2 mg (2 mol %) of palladium(II) acetate, and 34 mg (8 mol %) of BINAP were added in succession under stirring in a stream of argon, and the mixture was heated for 7 h at 110°C until initial compound **I** disappeared (TLC; strong tarring was observed) and evaporated. The residue was subjected to column chromatography on silica gel to isolate 34 mg (18%) of compound **IIIb**.

f. Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 176 mg (1 mmol) of aniline **IIb**, 2.2 mg (2 mol %) of palladium(II) acetate, 44 mg (8 mol %) of Xantphos, and 0.07 ml (0.65 mmol) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 7 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. Column chromatography of the residue on silica gel gave 100 mg (50%) of compound **IIIb**. mp 128–129°C (from diethyl ether). IR spectrum, ν, cm^{-1}: 3339, 3065, 2963, 2852, 2794, 1731, 1608, 1500, 1432, 1426, 1212, 1138, 1048, 869, 744, 601. UV spectrum (EtOH), λ_{max}, nm (log ε): 216 (4.45), 249 (4.35), 290 (3.97), 334 (3.71). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.40 d [6H, $(CH_3)_2CH$, J = 7.0 Hz], 1.57 m (4H, 3″-H, 5″-H), 3.08 m [1H, $CH(CH_3)_2$], 3.16 m (6H, 2″-H, 4″-H, 6″-H), 3.97 br.s (1H, NH), 6.44 d (1H, 6-H, J = 9.8 Hz), 6.72 d (1H, 3′-H, J = 7.6 Hz), 6.74 t (1H, 5′-H, J = 7.6 Hz), 6.91 t (1H, 4′-H, J = 7.6 Hz), 6.99 d (1H, 6′-H, J = 7.6 Hz), 7.42 s (1H, 9-H), 7.59 s (1H, 4-H), 7.78 d (1H, 5-H, J = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.67 q [$(CH_3)_2CH$], 24.22 t ($C^{3''}$, $C^{5''}$), 29.84 d [$CH(CH_3)_2$], 33.20 t ($C^{4''}$), 53.66 t ($C^{2''}$, $C^{6''}$), 100.18 d (C^9), 114.90 s

($C^{3'}$), 115.42 s (C^{4a}), 118.32 d (C^{6}), 119.03 s (C^{3a}), 119.64 d ($C^{4'}$), 120.17 d (C^{4}), 124.09 d ($C^{5'}$, $C^{6'}$), 124.10 s (C^{3}), 140.59 s and 141.39 s ($C^{1'}$, $C^{2'}$), 143.43 d (C^{5}); 152.41 s, 153.08 s, 156.97 s (C^{2}, C^{8a}, C^{9a}), 160.45 s (C^{7}). Found: N 6.92%. $C_{25}H_{26}N_2O_3$. Calculated: N 6.96%.

3-(3-Chlorophenylamino)-2-isopropyl-7*H*-furo[3,2-*g*]chromen-7-one (IIIc) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 127 mg (1 mmol) of 3-chloroaniline (**IIc**). Yield 109 mg (58%), mp 113–114°C (from diethyl ether). IR spectrum, ν, cm^{-1}: 3464, 3370, 3060, 2970, 2930, 2874, 1723, 1652, 1623, 1596, 1538, 1484, 1450, 1397, 1319, 1255, 1142, 1121, 1098, 1077, 992, 888, 853, 824, 770, 681. UV spectrum (EtOH), λ_{max}, nm (logε): 223 (4.12), 242 (4.33), 288 (3.89), 333 (3.69). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.27 d [6H, (C**H**$_3$)$_2$CH, J = 7.0 Hz], 3.09 m [1H, C**H**(CH$_3$)$_2$], 4.05 br.s (1H, NH), 6.31 d (1H, 6-H, J = 9.8 Hz), 6.97 d.d (1H, 4′-H, J = 7.5, 2.2 Hz), 7.19 s (1H, 9-H), 7.26 t (1H, 5′-H, J = 7.5 Hz), 7.38 d.d (1H, 6′-H, J = 7.5, 1.6 Hz), 7.50 s (1H, 4-H), 7.75 d (1H, 5-H, J = 9.8 Hz), 7.99 d.d (1H, 2′-H, J = 2.2, 1.6 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.39 q [(**C**H$_3$)$_2$CH], 25.28 d [**C**H(CH$_3$)$_2$], 99.04 d (C^{9}), 114.21 d (C^{6}), 114.40 s (C^{4a}), 114.96 d ($C^{2'}$), 121.65 d (C^{4}), 121.81 s (C^{3a}), 123.72 d ($C^{6'}$), 125.10 s (C^{3}), 129.41 d ($C^{4'}$), 134.06 d ($C^{5'}$), 138.37 s ($C^{3'}$), 143.10 d (C^{5}), 144.41 s ($C^{1'}$); 151.12 s, 157.79 s, 160.45 s (C^{2}, C^{7}, C^{8a}, C^{9a}). Found, %: Cl 10.58; N 4.13. $C_{20}H_{16}ClNO_3$. Calculated, %: Cl 10.02; N 3.96.

3-(3-Fluorophenylamino)-2-isopropyl-7*H*-furo[3,2-*g*]chromen-7-one (IIId) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 111 mg (1 mmol) of 3-fluoroaniline (**IId**). Yield 99 mg (55%), mp 115–116°C. IR spectrum, ν, cm^{-1}: 3365, 3081, 2971, 2929, 2878, 1720, 1696, 1625, 1508, 1456, 1430, 1340, 1330, 1052, 905, 879, 825, 665. UV spectrum (EtOH), λ_{max}, nm (logε): 221 (4.09), 238 (4.21), 286 (3.77), 330 (3.65). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.27 d [6H, (C**H**$_3$)$_2$CH, J = 7.0 Hz], 3.08 m [1H, C**H**(CH$_3$)$_2$], 3.81 br.s (1H, NH), 6.31 d (1H, 6-H, J = 9.7 Hz), 6.66 m (1H, 4′-H), 6.88 m (1H, 2′-H, J_{HF} = 9.8 Hz), 7.08 d.d (1H, 6′-H, J = 7.8, 1.6 Hz), 7.19 s (1H, 9-H), 7.35 m (1H, 5′-H, J = 2.2, 1.6 Hz), 7.50 s (1H, 4-H), 7.74 d (1H, 5-H, J = 9.7 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.50 q [(**C**H$_3$)$_2$CH], 25.23 d [**C**H(CH$_3$)$_2$], 104.87 d (C^{9}), 109.10 d ($C^{2'}$, J_{CF} = 9.5 Hz), 110.09 d ($C^{4'}$, J_{CF} = 9.2 Hz), 111.19 d ($C^{6'}$), 114.14 d (C^{6}), 115.88 s (C^{4a}), 119.30 d (C^{4}), 121.61 s (C^{3a}), 130.65 s (C^{3}), 141.49 d ($C^{5'}$), 143.05 s ($C^{1'}$), 143.73 d (C^{5}); 146.44 s, 157.69 s, 159.63 s, 159.91 s (C^{2}, C^{7}, C^{8a}, C^{9a}); 165.60 d ($C^{3'}$, J_{CF} = 274.6 Hz). Found, %: C 71.03; H 3.99; F 5.28; N 4.03. $C_{20}H_{16}FNO_3$. Calculated, %: C 71.21; H 4.78; F 5.63; N 4.15.

3-(2-Fluoro-6-trifluoromethylphenylamino)-2-isopropyl-7*H*-furo[3,2-*g*]chromen-7-one (IIIe) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 178 mg (1 mmol) of 2-fluoro-6-trifluoromethylaniline (**IIe**) (reaction time 7 h). Yield 60 mg (28%), oily substance. IR spectrum, ν, cm^{-1}: 3426, 2979, 1732, 1633, 1650, 1580, 1458, 1429, 1348, 1199, 1139, 1114, 1047, 958, 867, 821, 761, 740, 678. UV spectrum (EtOH), λ_{max}, nm (logε): 204 (4.55), 252 (4.69), 280 (4.23), 338 (4.09). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.23 d [6H, (C**H**$_3$)$_2$CH, J = 7.0 Hz], 3.10 m [1H, C**H**(CH$_3$)$_2$], 4.08 br.s (1H, NH), 6.25 d (1H, 6-H, J = 9.8 Hz), 6.53 m (1H, 3′-H), 6.98 m (1H, 4′-H), 7.04 d (1H, 5′-H, J = 7.6 Hz), 7.09 s (1H, 9-H), 7.41 s (1H, 4-H), 7.64 d (1H, 5-H, J = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.29 q [(**C**H$_3$)$_2$CH], 25.93 d [**C**H(CH$_3$)$_2$], 100.52 d (C^{9}), 113.99 d ($C^{3'}$), 114.63 d (C^{6}), 114.75 d ($C^{4'}$), 115.88 s (C^{4a}), 117.80 s ($C^{6'}$), 121.57 d (C^{4}), 122.61 q (CF_3), 122.86 d ($C^{5'}$), 124.15 s (C^{3a}), 125.72 s (C^{3}), 142.85 s ($C^{1'}$), 143.53 d (C^{5}); 153.06 s, 156.96 s, 157.57 s, 160.38 s (C^{2}, C^{7}, C^{8a}, C^{9a}); 163.57 d ($C^{2'}$). Found, %: C 61.03; H 4.09; F 15.28; N 3.13. $C_{21}H_{15}F_4NO_3$. Calculated, %: C 62.23; H 3.73; F 18.75; N 3.46.

3-(5-Fluoro-2-trifluoromethylphenylamino)-2-isopropyl-7*H*-furo[3,2-*g*]chromen-7-one (IIIf) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 178 mg (1 mmol) of 5-fluoro-2-trifluoromethylaniline (**IIf**). Yield 80 mg (37%), oily substance. IR spectrum, ν, cm^{-1}: 3438, 3060, 2939, 2881, 1731, 1660, 1633, 1579, 1429, 1250, 1201, 1139, 1115, 1047, 868, 821, 601. UV spectrum (EtOH), λ_{max}, nm (logε): 202 (4.3), 250 (4.44), 285 (3.99), 334 (3.84). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.24 d [6H, (C**H**$_3$)$_2$CH, J = 7.0 Hz], 3.05 m [1H, C**H**(CH$_3$)$_2$], 4.08 br.s (1H, NH), 6.28 d (1H, 6-H, J = 9.8 Hz), 6.57 d (1H, 6′-H, J = 8.8 Hz), 7.00 d.d (1H, 4′-H, J = 8.8, 7.8 Hz), 7.16 s (1H, 9-H), 7.54 s (1H, 4-H), 7.66 t (1H, 3′-H, J = 7.8 Hz), 7.71 d (1H, 5-H, J = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.66 q [(**C**H$_3$)$_2$CH], 23.02 d [**C**H(CH$_3$)$_2$], 99.43 d (C^{9}), 111.01 d and 111.47 d ($C^{4'}$, $C^{6'}$), 112.74 s ($C^{2'}$); 114.29 d and 114.48 d (C^{6}, $C^{3'}$), 115.56 s (C^{4a}), 116.79 s (C^{3a}), 122.16 q (CF_3, J = 287.8 Hz), 123.73 d (C^{4}), 125.72 s (C^{3}), 139.32 s ($C^{1'}$), 143.21 d (C^{5});

144.49 s, 151.20 s, 159.86 s, 160.49 s (C^2, C^7, C^{8a}, C^{9a}); 163.45 d ($C^{5'}$, J_{CF} = 261.7 Hz). Found, %: C 59.93; H 3.39; F 17.08; N 3.23. $C_{21}H_{15}F_4NO_3$. Calculated, %: C 62.23; H 3.73; F 18.75; N 3.46.

3-(4-Fluoro-2-trifluoromethylphenylamino)-2-isopropyl-7*H*-furo[3,2-*g*]chromen-7-one (IIIg) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 178 mg (1 mmol) of 4-fluoro-2-trifluoromethylaniline (**IIg**) (reaction time 7 h). Yield 67 mg (31%), oily substance. IR spectrum, ν, cm^{-1}: 3440, 3061, 2927, 1731, 1659, 1633, 1550, 1429, 1348, 1288, 1250, 1201, 1140, 1115, 958, 868, 821. UV spectrum (EtOH), λ_{max}, nm (logε): 200 (4.75), 252 (4.89), 284 (4.44), 334 (4.29). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.38 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 3.27 m [1H, C**H**(CH$_3$)$_2$], 3.92 br.s (1H, NH), 6.42 d (1H, 6-H, *J* = 9.8 Hz), 7.00 d (1H, 6′-H, *J* = 8.6 Hz), 7.03 d (1H, 5′-H, *J* = 8.6 Hz), 7.14 s (1H, 9-H), 7.15 s (1H, 3′-H), 7.58 s (1H, 4-H), 7.80 d (1H, 5-H, *J* = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.64 q [(**C**H$_3$)$_2$CH], 23.83 d [**C**H(CH$_3$)$_2$], 100.09 d (C^9), 111.66 d (C^3), 112.16 s ($C^{5'}$), 114.46 d and 114.63 d (C^6, C^{4a}), 116.55 s (C^{3a}), 118.32 d ($C^{3'}$), 121.32 s ($C^{6'}$), 122.87 d ($C^{2'}$), 122.95 q (CF_3, *J* = 286.1 Hz), 123.92 d (C^4), 136.35 s ($C^{1'}$), 144.65 d (C^5); 143.37 s, 151.37 s, 158.06 s, 161.19 s (C^2, C^7, C^{8a}, C^{9a}); 160.64 d ($C^{4'}$, J_{CF} = 259.7 Hz). Found, %: C 60.03; H 4.09; F 18.28; N 3.33. $C_{21}H_{15}F_4NO_3$. Calculated, %: C 62.23; H 3.73; F 18.75; N 3.46.

3-(4-Fluoro-3-trifluoromethylphenylamino)-2-isopropyl-7*H*-furo[3,2-*g*]chromen-7-one (IIIh) was synthesized as described above in *a* from 200 mg (0.5 mmol) of trifluoromethanesulfonate **I** and 178 mg (1 mmol) of 4-fluoro-3-trifluoromethylaniline (**IIh**). Yield 103 mg (48%), mp 123–124°C (from diethyl ether). IR spectrum, ν, cm^{-1}: 3428, 3062, 2852, 1729, 1626, 1574, 1483, 1325, 1290, 1141, 1103, 910, 825, 753, 701. UV spectrum (EtOH), λ_{max}, nm (logε): 202 (4.48), 253 (4.25), 297 (3.90), 337 (3.90). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.20 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 3.02 m [1H, C**H**(CH$_3$)$_2$], 4.04 br.s (1H, NH), 6.24 d (1H, 6-H, *J* = 9.8 Hz), 7.12 s (1H, 9-H), 7.40 m (1H, 5′-H), 7.43 s (1H, 4-H), 7.47 d.d (1H, 6′-H, *J* = 8.6, 2.2 Hz), 7.67 d (1H, 5-H, *J* = 9.8 Hz), 8.20 m (1H, 2′-H). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.28 q [(**C**H$_3$)$_2$CH], 21.85 d [**C**H(CH$_3$)$_2$], 99.92 d (C^9), 110.10 d ($C^{2'}$), 114.09 d (C^6), 114.31 s (C^{4a}), 114.50 d ($C^{5'}$), 117.27 d ($C^{3'}$), 117.79 d (C^4), 119.91 q (CF_3, *J* = 287.6 Hz), 120.56 s (C^{3a}), 121.75 d ($C^{6'}$), 128.63 s (C^3), 137.37 s ($C^{1'}$), 143.38 d (C^5), 154.18 d ($C^{4'}$, J_{CF} = 269.6 Hz); 143.22 s, 144.47 s, 157.89 s, 160.77 s (C^2, C^7, C^{8a}, C^{9a}). ^{19}F NMR spectrum, δ_F, ppm: 32.51 m (CF_3), 100.43 d (F). Found, %: C 62.02; H 3.99; F 18.35; N 3.06. $C_{21}H_{15}F_4NO_3$. Calculated, %: C 62.23; H 3.73; F 18.75; N 3.46.

2-Isopropyl-3-[4-methyl-3-(trifluoromethyl)-phenylamino]-7*H*-furo[3,2-*g*]chromen-7-one (IIIi) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 175 mg (1 mmol) of 4-methyl-3-trifluoromethylaniline (**IIi**) (reaction time 5 h). Yield 141 mg (66%), mp 121–122°C (from diethyl ether). IR spectrum, ν, cm^{-1}: 3430, 3403, 2931, 1731, 1650, 1633, 1321, 1288, 1250, 1201, 1139, 958, 868, 820, 761, 707. UV spectrum (EtOH), λ_{max}, nm (logε): 201 (4.61), 239 sh (4.32), 252 (4.33), 300 sh (4.06), 337 (3.91), 350 sh (3.85). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.23 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 2.25 s (3H, CH_3), 3.11 m [1H, C**H**(CH$_3$)$_2$], 3.74 br.s (1H, NH), 6.25 d (1H, 6-H, *J* = 9.8 Hz), 7.04 d (1H, 5′-H, *J* = 7.2 Hz), 7.10 s (1H, 9-H), 7.22 d.d (1H, 6′-H, *J* = 7.2, 2.0 Hz), 7.39 d (1H, 2′-H, *J* = 2.0 Hz), 7.42 s (1H, 4-H), 7.64 d (1H, 5-H, *J* = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.57 q [(**C**H$_3$)$_2$CH, 4′-CH_3], 26.24 d [**C**H(CH$_3$)$_2$], 100.81 d (C^9), 110.65 d ($C^{2'}$), 114.35 s (C^{4a}), 115.84 d (C^6), 116.95 d (C^4), 117.80 s ($C^{4'}$), 119.32 s (C^{3a}), 122.01 q (CF_3), 123.61 d ($C^{6'}$), 125.31 s (C^3), 131.15 s ($C^{3'}$), 132.51 d ($C^{5'}$), 136.16 s ($C^{1'}$), 143.80 d (C^5); 143.90 s, 152.39 s, 157.20 s, 160.76 s (C^2, C^7, C^{8a}, C^{9a}). Found, %: F 14.00; N 3.06. $C_{22}H_{18}F_3NO_3$. Calculated, %: F 14.20; N 3.49.

2-Isopropyl-3-[4-methylsulfanyl-3-(trifluoro-methyl)phenylamino]-7*H*-furo[3,2-*g*]chromen-7-one (IIIj) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 207 mg (1 mmol) of 4-methylsulfanyl-3-trifluoromethylaniline (**IIj**) (reaction time 4 h). Yield 170 mg (74%), mp 138–139°C (from diethyl ether). IR spectrum, ν, cm^{-1}: 3337, 3185, 3058, 2962, 2952, 1735, 1727, 1681, 1624, 1573, 1483, 1350, 1334, 1289, 1252, 1139, 1120, 1101, 1043, 908, 823, 745, 724, 695. UV spectrum (EtOH), λ_{max}, nm (logε): 206 (4.38), 239 (4.26), 251 (4.28), 295 sh (3.91), 337 (3.86), 350 sh (3.80). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.28 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 2.55 s (3H, CH_3S), 3.09 m [1H, C**H**(CH$_3$)$_2$], 3.74 br.s (1H, NH), 6.31 d (1H, 6-H, *J* = 9.8 Hz), 7.19 s (1H, 9-H), 7.21 d.d (1H, 6′-H, *J* = 7.5, 1.2 Hz), 7.46 d (1H, 5′-H, *J* = 7.5 Hz), 7.48 s (1H, 4-H), 7.75 d (1H, 5-H, *J* = 9.8 Hz), 7.82 s (1H, 2′-H, *J* = 1.2 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 19.48 q (CH_3S), 20.29 q [(**C**H$_3$)$_2$CH], 25.93 d [**C**H(CH$_3$)$_2$], 100.52 d (C^9), 113.23 d ($C^{2'}$), 113.34 s

(C^{4a}), 115.57 d (C^6), 116.04 d (C^4), 116.75 s ($C^{4'}$), 118.99 s (C^{3a}), 120.07 d ($C^{6'}$), 122.01 q (CF_3), 125.04 s (C^3), 126.18 d ($C^{5'}$), 130.80 s ($C^{3'}$), 134.40 s ($C^{1'}$), 143.56 d (C^5); 145.12 s, 152.23 s, 156.95 s, 160.39 s (C^2, C^7, C^{8a}, C^{9a}). Found, %: F 14.00; N 3.06; S 7.12. $C_{22}H_{18}F_3NO_3S$. Calculated, %: F 13.15; N 3.23; S 7.40.

2-Isopropyl-3-[2-morpholino-5-(trifluoromethyl)-phenylamino]-7*H*-furo[3,2-*g*]chromen-7-one (IIIk) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 246 mg (1 mmol) of 2-morpholino-5-trifluoromethylaniline (**IIk**) (reaction time 6 h). Yield 113 mg (45%), oily substance. IR spectrum, ν, cm^{-1}: 3463, 3297, 3078, 2969, 2855, 2743, 1738, 1626, 1578, 1531, 1483, 1470, 1436, 1354, 1331, 1285, 1246, 1157, 1140, 1031, 910, 852, 828, 758, 639. UV spectrum (EtOH), λ_{max}, nm (logε): 228 (3.99), 231 (4.02), 252 (4.21), 295 (3.79), 339 (3.80), 361 sh (3.71). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.19 d [6H, (CH_3)$_2$CH, J = 7.0 Hz], 3.00 m [1H, C**H**(CH_3)$_2$], 3.40–3.70 m (9H, NCH_2CH_2O, NH), 6.23 d (1H, 6-H, J = 9.8 Hz), 6.92 d (1H, 3′-H, J = 8.8 Hz), 7.11 s (1H, 9-H), 7.31 d.d (1H, 4′-H, J = 8.8, 1.9 Hz), 7.42 s (1H, 4-H), 7.47 s (1H, 6′-H, J = 1.9 Hz), 7.66 d (1H, 5-H, J = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 29.61 q [(CH_3)$_2$CH], 31.05 d [**C**H(CH_3)$_2$], 50.98 t (CH_2N), 67.41 t (CH_2O), 100.86 d (C^9), 107.17 d ($C^{6'}$), 113.72 s (C^{4a}), 113.99 d ($C^{3'}$), 114.56 d (C^6), 115.55 d (C^4), 119.50 d ($C^{4'}$), 120.86 q (CF_3), 124.31 s (C^{3a}), 125.26 s ($C^{5'}$), 127.31 s (C^3), 140.20 s and 141.22 s ($C^{1'}$, $C^{2'}$), 143.53 d (C^5); 142.32 s, 152.99 s, 159.87 s, 160.94 s (C^2, C^7, C^{8a}, C^{9a}). Found, %: F 11.97; N 6.48. $C_{25}H_{23}F_3N_2O_4$. Calculated, %: F 12.06; N 5.93.

2-Isopropyl-3-[2-piperidino-6-(trifluoromethyl)-phenylamino]-7*H*-furo[3,2-*g*]chromen-7-one (IIIl) was synthesized as described above in *a* from 200 mg (0.5 mmol) of compound **I** and 244 mg (1 mmol) of 2-piperidino-6-trifluoromethylaniline (**IIl**) (reaction time 6 h). Yield 123 mg (49%), mp 132–133°C (from diethyl ether). IR spectrum, ν, cm^{-1}: 3400, 3180, 3066, 2952, 2854, 1726, 1672, 1624, 1571, 1555, 1484, 1466, 1450, 1392, 1351, 1331, 1289, 1191, 1143, 1101, 1080, 946, 910, 824, 756, 742, 700. UV spectrum (EtOH), λ_{max}, nm (logε): 203 (4.46), 254 (4.40), 299 (4.00), 307 (3.99), 345 (4.02). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.20 d [6H, (CH_3)$_2$CH, J = 7.0 Hz], 1.42–1.58 m (6H, CH_2), 3.02 m [1H, C**H**(CH_3)$_2$], 3.02–3.35 m (5H, NCH_2, NH), 6.24 d (1H, 6-H, J = 9.8 Hz), 6.41 d.d (1H, 3′-H, J = 7.8, 1.2 Hz), 7.06 t (1H, 4′-H, J = 7.8 Hz), 7.12 s (1H, 9-H), 7.38 d.d (1H, 5′-H, J = 7.7, 1.2 Hz), 7.50 s (1H, 4-H), 7.67 d (1H, 5-H, J = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.63 q [(CH_3)$_2$CH], 21.44 d [**C**H(CH_3)$_2$], 99.76 d (C^9), 107.85 s (C^3), 113.93 d (C^{3a}), 114.26 d (C^6), 114.45 s (C^{4a}), 115.57 d (C^6), 116.52 d ($C^{6'}$), 116.74 d ($C^{2'}$), 117.41 s ($C^{4'}$), 118.65 q (CF_3), 122.47 d (C^4), 125.36 d ($C^{5'}$), 128.48 s ($C^{1'}$), 144.46 d (C^5); 143.17 s, 151.17 s, 157.98 s, 160.65 s (C^2, C^7, C^{8a}, C^{9a}). Found, %: F 11.56; N 5.33. $C_{26}H_{25}F_3N_2O_3$. Calculated, %: F 12.11; N 5.95.

2-Isopropyl-3-(quinolin-6-ylamino)-7*H*-furo-[3,2-*g*]chromen-7-one (VII). Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 144 mg (1 mmol) of quinolin-6-amine (**IV**), 2.2 mg (2 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (1.3 equiv) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 6 h at 115°C (TLC) and evaporated. The product was isolated by column chromatography on silica gel. Yield 88 mg (45%), mp 130–131°C (from diethyl ether). IR spectrum, ν, cm^{-1}: 3408, 3319, 3186, 3059, 2958, 2850, 1730, 1676, 1630, 1581, 1506, 1431, 1378, 1335, 1294, 1224, 1182, 1136, 1101, 1059, 960, 902, 874, 835, 791, 754, 656. UV spectrum (EtOH), λ_{max}, nm (logε): 207 (4.41), 244 (4.58), 274 (3.90), 285 (3.89), 321 (3.67), 335 (3.62), 351 (3.88). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.23 d [6H, (CH_3)$_2$CH, J = 7.0 Hz], 3.05 m [1H, C**H**(CH_3)$_2$], 6.27 d (1H, 6-H, J = 9.8 Hz), 7.15 s (1H, 9-H), 7.23–7.33 m (2H, 3′-H, 7′-H), 7.46 s (1H, 4-H), 7.70 d (1H, 5-H, J = 9.8 Hz), 7.75 d (1H, 8′-H, J = 8.8 Hz), 7.85 d (1H, 5′-H, J = 1.8 Hz), 7.87 d.d (1H, 4′-H, J = 5.8, 0.8 Hz), 9.05 d.d (1H, 2′-H, J = 5.8, 1.6 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.75 q [(CH_3)$_2$CH], 22.08 d [**C**H(CH_3)$_2$], 99.52 d (C^9), 110.20 d ($C^{3'}$), 114.69 s (C^{4a}), 115.13 d (C^6), 117.18 d (C^4), 120.83 s (C^{3a}), 121.23 d, 121.79 d ($C^{5'}$, $C^{8'}$), 125.97 s (C^3), 130.50 d ($C^{7'}$), 131.00 s ($C^{4a'}$), 137.90 d ($C^{4'}$), 139.14 s ($C^{8a'}$), 141.77 d ($C^{6'}$), 142.20 d ($C^{2'}$), 144.55 d (C^5), 151.26 s (C^{8a}), 156.95 s (C^{9a}), 157.98 s (C^2), 160.63 s (C^7). Found, %: C 75.12; H 4.71; N 6.80. $C_{23}H_{18}N_2O_3$. Calculated, %: C 74.58; H 4.90; N 7.56.

Compounds **VIII** and **IX** were synthesized in a similar way.

2-Isopropyl-3-(quinolin-8-ylamino)-7*H*-furo-[3,2-*g*]chromen-7-one (VIII) was synthesized from 200 mg (0.5 mmol) of compound **I** and 144 mg (1 mmol) of quinolin-8-amine (**V**). Yield 63 mg (32%). IR spectrum, ν, cm^{-1}: 3451, 3352, 3063, 3038, 2963, 2874, 2853, 1726, 1711, 1680, 1628, 1600, 1576,

1528, 1506, 1500, 1472, 1371, 1155, 1142, 1120, 1103, 1043, 822, 791, 758, 748. UV spectrum (EtOH), λ_{max}, nm (log ε): 205 (4.32), 250 (4.51), 299 (3.68), 307 (3.99), 338 (4.18), 351 (4.15). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.27 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 3.15 m [1H, C**H**(CH$_3$)$_2$], 4.04 br.s (1H, NH), 6.24 d (1H, 6-H, *J* = 9.6 Hz), 6.83 d (1H, 5′-H, *J* = 7.1 Hz), 7.01 d (1H, 7′-H, *J* = 7.1 Hz), 7.19 m (2H, 3′-H, 6′-H), 7.22 s (1H, 9-H), 7.43 s (1H, 4-H), 7.64 d (1H, 5-H, *J* = 9.6 Hz), 7.93 d (1H, 4′-H), 8.59 d (1H, 2′-H). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.07 q [(**C**H$_3$)$_2$CH], 25.69 d [**C**H(CH$_3$)$_2$], 100.10 d (C^9), 110.10 d (C$^{5'}$), 115.11 s (C^6), 115.79 d (C$^{7'}$), 115.94 s (C^{4a}), 116.46 d (C^4), 120.96 d (C$^{3'}$), 126.08 d (C^{3a}), 127.16 d (C$^{6'}$), 128.66 s (C^3), 134.74 s (C$^{4a'}$), 136.03 d (C$^{4'}$), 138.01 s (C^{8a}), 140.56 s (C$^{8'}$), 143.71 d (C^5), 147.06 d (C$^{2'}$), 151.94 s, 153.08 s (C^{8a}, C^{9a}), 156.90 s (C^2), 160.78 s (C^7). Found, %: C 74.42; H 4.62; N 7.10. $C_{23}H_{18}N_2O_3$. Calculated, %: C 74.58; H 4.90; N 7.56.

2-Isopropyl-3-(isoquinolin-5-ylamino)-7*H*-furo-[3,2-*g*]chromen-7-one (IX) was synthesized from 200 mg (0.5 mmol) of trifluoromethanesulfonate **I** and 144 mg (1 mmol) of isoquinolin-5-amine (**VI**). Yield 95 mg (48%). IR spectrum, ν, cm^{-1}: 3516, 3070, 3059, 3040, 2877, 1729, 1713, 1677, 1630, 1576, 1511, 1484, 1357, 1335, 1280, 1246, 1160, 1145, 1107, 1047, 1031, 980, 960, 950, 920, 823, 772, 759, 639. UV spectrum (EtOH), λ_{max}, nm (log ε): 223 (3.94), 228 (3.96), 234 (4.05), 252 (4.30), 297 (3.81), 308 (3.83), 342 (3.99), 353 (3.99). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.24 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 3.04 m [1H, C**H**(CH$_3$)$_2$], 3.92 br.s (1H, NH), 6.25 d (1H, 6-H, *J* = 9.7 Hz), 7.14 s (1H, 9-H), 7.28 t (1H, 7′-H, *J* = 7.7 Hz), 7.41 d (1H, 6′-H, *J* = 7.7 Hz), 7.43 d (1H, 8′-H, *J* = 7.7, 1.6 Hz), 7.45 s (1H, 4-H), 7.71 d (1H, 5-H, *J* = 9.7 Hz), 8.21 d (1H, 4′-H, *J* = 6.2 Hz), 8.37 d.d (1H, 3′-H, *J* = 6.2, 0.8 Hz), 8.75 br.s (1H, 1′-H). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.20 q [(**C**H$_3$)$_2$CH], 25.94 d [**C**H(CH$_3$)$_2$], 100.52 d (C^9), 104.84 d (C$^{6'}$), 109.55 d (C$^{8'}$), 113.15 s (C^{4a}); 114.11 d, 115.57 d, 116.60 d (C^4, C^6, C$^{4'}$); 124.93 s (C^{3a}), 125.76 s (C$^{8a'}$), 127.86 s (C^3), 130.63 d (C$^{7'}$), 132.57 s (C$^{4a'}$), 142.93 s (C$^{5'}$), 143.20 d (C$^{3'}$), 143.52 d (C^5), 145.82 s (C^{9a}), 153.06 s (C^{8a}), 156.91 s (C^2), 161.29 s (C^7), 164.24 s (C$^{1'}$). Found, %: C 75.07; H 5.06; N 7.60. $C_{23}H_{18}N_2O_3$. Calculated, %: C 74.58; H 4.90; N 7.56.

2-Isopropyl-3-[2-(pyridin-3-yl)piperidin-1-yl]-7*H*-furo[3,2-*g*]chromen-7-one (XII). *a*. Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 160 mg (1 mmol) of anabasine (**X**), 2 mol % of palladium(II) acetate, 8 mol % of BINAP, and 0.07 ml (1.3 equiv) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 7 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel to isolate 132 mg (68%) of compound **XII**.

b. Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 160 mg (1 mmol) of anabasine (**X**), 44 mg (8 mol %) of Xantphos, 4.4 mg (4 mol %) of palladium(II) acetate, and 0.07 ml (1.3 equiv) of triethylamine were added under stirring in a stream of argon, and the mixture was stirred for 7 h at 115°C and evaporated. By column chromatography on silica gel we isolated 118 mg (53%) of compound **XII**, mp 135–136°C, $[\alpha]_D^{20}$ = –33.6° (*c* = 1.0, $CHCl_3$). IR spectrum, ν, cm^{-1}: 3431, 3054, 2980, 2931, 2854, 1732, 1631, 1579, 1456, 1429, 1388, 1348, 1321, 1288, 1201, 1140, 1115, 1047, 920, 868, 819, 720. UV spectrum (EtOH), λ_{max}, nm (log ε): 202 (4.53), 250 (4.47), 284 (3.99), 332 (3.82). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.27 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 1.40–1.68 m (4H, 5′-H, 6′-H), 1.70–1.90 m (2H, 3′-H), 2.72 m (1H, 6′-H), 3.14 m [2H, 6′-H, C**H**(CH$_3$)$_2$], 3.67 d.d (1H, 2′-H, *J* = 3.8, 1.2 Hz), 6.28 d (1H, 6-H, *J* = 9.8 Hz), 6.12 m (1H, 5″-H), 7.28 s (1H, 9-H), 7.48 s (1H, 4-H), 7.72 d (1H, 5-H, *J* = 9.8 Hz), 7.33 m (1H, 4″-H), 8.33 m (1H, 6″-H), 8.49 br.s (1H, 2″-H). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.07 q [(**C**H$_3$)$_2$CH], 23.41 d [**C**H(CH$_3$)$_2$], 23.89 t (C$^{4''}$), 25.72 t (C$^{5'}$), 32.36 t (C$^{3'}$), 46.41 t (C$^{6'}$), 58.96 d (C$^{2'}$), 100.26 d (C^9), 110.64 s (C^{4a}), 115.29 d (C^6), 115.86 s (C^{3a}), 119.95 d (C^4), 123.51 d (C$^{5''}$), 126 s (C^3), 134.94 d (C$^{4''}$), 140.47 s (C$^{3''}$), 141.44 d (C^5), 148.57 d and 148.93 d (C$^{2''}$, C$^{6''}$); 143.48 s, 152.02 s, 156.76 s, 160.19 s (C^2, C^7, C^{8a}, C^{9a}). Found, %: C 73.30; H 6.06; N 7.12. $C_{24}H_{24}N_2O_3$. Calculated, %: C 74.21; H 6.23; N 7.21.

***tert*-Butyl 4-(2-isopropyl-7-oxo-7*H*-furo[3,2-*g*]-chromen-3-yl)piperazine-1-carboxylate (XIIIa).** *a*. Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 186 mg (1 mmol) of *tert*-butyl piperazine-1-carboxylate (**XIa**), 2.2 mg (2 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (1.3 equiv) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 7 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel to isolate 88 mg (43%) of compound **XIIIa**.

b. Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 167 mg (0.9 mmol) of *tert*-butyl piperazine-1-carboxylate (**XIa**), 44 mg (8 mol %) of Xantphos, 4.4 mg (4 mol %) of palladium(II) acetate, and 0.07 ml (1.3 equiv) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 7 h at 115°C and evaporated. The residue was subjected to column chromatography on silica gel to isolate 92 mg (45%) of **XIIIa**. When 140 mg (0.75 mmol) of piperazine **XIa** was added in 70-mg portions through a time interval of 2 h (the first portion was added in 30 min after addition of all other reagents), the yield of **XIIIa** was 82 mg (40%).

c. Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 186 mg (1 mmol) of piperazine **XIa**, 2.2 mg (2 mol %) of palladium(II) acetate, 10 mg (8 mol %) of tris(*tert*-butyl)phosphine, and 0.07 ml (1.3 equiv) of triethylamine were added under stirring in a stream of argon, and the mixture was heated for 7 h at 115°C and evaporated. Column chromatography of the residue on silica gel gave 72 mg (35%) of **XIIIa**, mp 152–153°C (from diethyl ether). IR spectrum, ν, cm^{-1}: 3434, 3080, 2979, 2933, 2860, 1732, 1691, 1635, 1579, 1550, 1470, 1429, 1390, 1367, 1348, 1286, 1249, 1211, 1197, 1171, 1140, 1117, 1047, 1009, 868, 820, 790, 602. UV spectrum (EtOH), λ_{max}, nm (log ε): 212 (3.99), 250 (4.26), 285 (3.77), 330 (3.62). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.37 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 1.43 s (9H, *t*-Bu), 2.77 m (4H, 2′-H, 6′-H), 3.14 m [1H, C**H**(CH$_3$)$_2$], 3.35 m (4H, 3′-H, 5′-H), 6.39 d (1H, 6-H, *J* = 9.7 Hz), 7.39 s (1H, 9-H), 7.55 s (1H, 4-H), 7.78 d (1H, 5-H, *J* = 9.7 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.25 q [(**C**H$_3$)$_2$CH], 25.89 d [**C**H(CH$_3$)$_2$], 28.36 q [C(**C**H$_3$)$_3$], 45.77 t (C$^{3'}$, C$^{5'}$), 50.35 t (C$^{2'}$, C$^{6'}$), 77.51 s [**C**(CH$_3$)$_3$], 100.44 d (C^9), 107.05 s (C^{3a}), 115.55 s (C^{4a}), 116.69 d (C^6), 120.26 d (C^4), 121.40 s (C^3), 143.39 d (C^5); 143.52 s, 152.20 s, 154.74 s, 156.83 s, 160.26 s (C^2, C^7, C^{8a}, C^{9a}, C=O). Found, %: C 65.89; H 6.70; N 6.45. $C_{23}H_{28}N_2O_5$. Calculated, %: C 66.97; H 6.84; N 6.79.

2-Isopropyl-3-(4-methylpiperazin-1-yl)-7*H*-furo-[3,2-*g*]chromen-7-one (XIIIb). Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 90 mg (0.9 mmol) of 4-methylpiperazine (**XIb**), 44 mg (8 mol %) of Xantphos, 0.07 ml (1.3 equiv) of triethylamine, and 4.4 mg (4 mol %) of palladium(II) acetate were added under stirring in a stream of argon, and the mixture was heated for 7 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel. Yield 71 mg (44%), mp 132–133°C. IR spectrum, ν, cm^{-1}: 3435, 3100, 3057, 2980, 2931, 2881, 2854, 2802, 1732, 1689, 1632, 1620, 1581, 1462, 1429, 1388, 1348, 1300, 1288, 1250, 1203, 1140, 1100, 1047, 900, 868, 822, 779, 760, 700, 680, 626. UV spectrum (EtOH), λ_{max}, nm (log ε): 203 (4.14), 250 (4.31), 284 (3.86), 331 (3.70). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.34 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 2.21 s (3H, CH$_3$), 2.32 m (4H, 3′-H, 5′-H), 2.84 m (4H, 2′-H, 6′-H), 3.22 m [1H, C**H**(CH$_3$)$_2$], 6.37 d (1H, 6-H, *J* = 9.7 Hz), 7.36 s (1H, 9-H), 7.53 s (1H, 4-H), 7.76 d (1H, 5-H, *J* = 9.7 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.23 q [(**C**H$_3$)$_2$CH], 25.86 d [**C**H(CH$_3$)$_2$], 45.13 q (CH$_3$), 46.36 t (C$^{2'}$, C$^{6'}$), 54.65 t (C$^{3'}$, C$^{5'}$), 100.44 d (C^9), 109.09 s (C^{3a}), 114.26 s (C^{4a}), 115.50 d (C^6), 118.91 d (C^4), 120.23 s (C^3), 143.52 d (C^5); 144.82 s, 152.66 s, 156.75 s, 160.31 (C^2, C^7, C^{8a}, C^{9a}). Found, %: C 68.85; H 6.35; N 8.45. $C_{19}H_{22}N_2O_3$. Calculated, %: C 69.92; H 6.79; N 8.58.

(2*S*,5*R*,6*R*)-6-(2-Isopropyl-7-oxo-7*H*-furo[3,2-*g*]-chromen-3-ylamino)-3,3-dimethyl-7-oxo-4-thia-1-azabicyclo[3.2.0]heptane-2-carboxylic acid (XVI). Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 216 mg (1 mmol) of 6-aminopenicillanic acid (**XIV**), 4.4 mg (4 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (1.3 equiv) of triethylamine were added under argon, and the mixture was heated for 6 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel, and a fraction containing compound **XVI** was ground with diethyl ether. Yield 145 mg (66%), mp 214–215°C (from diethyl ether), $[\alpha]_D^{20}$ = –86.4° (*c* = 0.2, H$_2$O–EtOH, 2:1). IR spectrum, ν, cm^{-1}: 3430, 3190, 3090, 3062, 2965, 2930, 2874, 1760, 1727, 1710, 1628, 1576, 1483, 1466, 1392, 1355, 1301, 1249, 1187, 1154, 1143, 1104, 1044, 978, 933, 900, 878, 830, 745, 705, 698. UV spectrum ($CHCl_3$–EtOH, 1:1), λ_{max}, nm (log ε): 253 (4.54), 296 (4.13), 310 (4.11), 342 (4.14), 354 (4.15). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 1.33 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 1.49 s and 1.68 s (3H each, CH$_3$), 3.26 m [1H, (CH$_3$)$_2$C**H**], 4.14 s (1H, 2′-H), 4.55 d (1H, 5′-H, *J* = 4.7 Hz), 5.38 m (1H, 6′-H, $J_{5',6'}$ = 4.7 Hz), 6.44 d (1H, 6-H, *J* = 9.8 Hz), 7.72 s (1H, 9-H), 7.85 s (1H, 4-H), 8.19 d (1H, 5-H, *J* = 9.8 Hz). ^{13}C NMR spectrum (DMSO-d_6), δ_C, ppm: 20.13 q [(**C**H$_3$)$_2$CH], 25.60 d [**C**H(CH$_3$)$_2$], 26.89 q (CH$_3$), 31.02 q (CH$_3$), 60.37 d (C$^{6'}$), 63.20 d (C$^{5'}$), 67.22 s (C$^{3'}$), 70.26 d (C$^{2'}$), 100.56 d (C^9), 116.27 s and 116.50 s (C^{3a}, C^{4a}),

117.92 d (C^6), 120.39 d (C^4), 126.10 s (C^3), 144.45 d (C^5), 151.98 s and 152.43 s (C^{8a}, C^{9a}), 156.56 s (C^2), 159.87 s (C^7), 169.50 s ($C^{7'}$), 178.44 s (2′-C=O). Found, %: C 59.60; H 4.77; N 6.08; S 6.89. $C_{22}H_{22}N_2O_6S$. Calculated, %: C 59.72; H 5.01; N 6.33; S 7.25.

Methyl (2*S*,5*R*,6*R*)-6-(2-isopropyl-7-oxo-7*H*-furo[3,2-*g*]chromen-3-ylamino)-3,3-dimethyl-7-oxo-4-thia-1-azabicyclo[3.2.0]heptane-2-carboxylate (XVII). Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 230 mg (1 mmol) of 6-aminopenicillanic acid methyl ester (**XV**), 4.4 mg (4 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (1.3 equiv) of triethylamine were added under argon, and the mixture was heated for 6 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel. Yield 104 mg (48%), mp 184–185°C (from diethyl ether), $[\alpha]_D^{20}$ = +206.4° (*c* = 0.5, $CHCl_3$). IR spectrum, ν, cm^{-1}: 3326, 2976, 2958, 2931, 2875, 1783, 1739, 1675, 1579, 1506, 1456, 1432, 1324, 1286, 1213, 1135, 1116, 1072, 1047, 1029, 929, 871, 819, 752, 665. UV spectrum (EtOH), λ_{max}, nm (logε): 192 (3.31), 209 (3.74), 243 (3.68), 250 (3.71), 287 (3.20), 330 (3.12). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.36 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 1.46 s and 1.61 s (3H each, CH_3), 3.24 m [1H, $(CH_3)_2$C**H**], 3.74 s (3H, OCH_3), 4.41 d (1H, NH), 4.37 s (1H, 3′-H), 4.54 d (1H, 5′-H, *J* = 4.8 Hz), 5.48 m (1H, 6′-H), 6.40 d (1H, 6-H, *J* = 9.8 Hz), 7.40 s (1H, 9-H), 7.56 s (1H, 4-H), 7.79 d (1H, 5-H, *J* = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 20.40 q [(**C**H$_3$)$_2$CH], 23.35 d [**C**H(CH$_3$)$_2$], 27.24 q (CH_3), 30.44 q (CH_3), 51.94 q (OCH_3), 65.14 d ($C^{6'}$), 67.09 d ($C^{5'}$), 68.33 s ($C^{3'}$), 75.79 d ($C^{2'}$), 100.30 d (C^9), 109.41 s (C^{4a}), 114.34 d (C^6), 114.93 d (C^4), 121.25 s (C^{3a}), 123.23 s (C^3), 142.44 d (C^5), 144.54 s (C^{9a}), 150.85 s (C^{8a}), 157.39 s (C^2), 160.64 s (C^7), 165.52 s ($C^{7'}$), 171.44 s (2′-C=O). Found, %: C 60.32; H 5.08; N 5.93; S 7.00. $C_{23}H_{24}N_2O_6S$. Calculated, %: C 60.51; H 5.30; N 6.14; S 7.02.

(6*R*,7*R*)-3-(Acetoxymethyl)-7-(2-isopropyl-7-oxo-7*H*-furo[3,2-*g*]chromen-3-ylamino)-8-oxo-5-thia-1-azabicyclo[4.2.0]oct-2-ene-2-carboxylic acid (XXI). Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 272 mg (1 mmol) of 7-aminocephalosporanic acid (**XVIII**), 4.4 mg (4 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (1.3 equiv) of triethylamine were added under argon, and the mixture was heated for 8 h at 120°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected by column chromatography on silica gel. Yield 89 mg (36%), mp 188–189°C (from diethyl ether), $[\alpha]_D^{20}$ = –209.6° (*c* = 0.5, H_2O–EtOH, 2:1). IR spectrum, ν, cm^{-1}: 3456, 3190, 3063, 2962, 2923, 2853, 1772, 1730, 1626, 1574, 1501, 1485, 1466, 1391, 1350, 1325, 1290, 1254, 1186, 1141, 1103, 1049, 943, 910, 876, 846, 826, 744, 710, 698. UV spectrum (EtOH), λ_{max}, nm (logε): 204 (4.06), 222 (3.95), 251 (4.17), 297 (3.70), 308 (3.68), 343 (3.79), 353 (3.80). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 1.27 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 2.09 s (3H, CH_3), 3.09 m [1H, $(CH_3)_2$C**H**], 3.52–3.69 m (2H, 4′-H), 4.96 m (2H, CH_2), 5.15 m (1H, 6′-H), 5.45 m (1H, 7′-H), 6.40 d (1H, 6-H, *J* = 9.8 Hz), 7.19 s (1H, 9-H), 7.43 s (1H, 4-H), 7.77 d (1H, 5-H, *J* = 9.8 Hz). ^{13}C NMR spectrum (DMSO-d_6), δ_C, ppm: 20.15 q (CH_3), 20.39 q [(**C**H$_3$)$_2$CH], 22.26 t ($C^{4'}$), 23.34 d [**C**H(CH$_3$)$_2$], 65.25 d ($C^{7'}$), 67.51 d ($C^{6'}$), 71.20 t (CH_2), 99.30 d (C^9), 106.95 s (C^{4a}), 113.90 s (C^{3a}), 114.33 d (C^6), 123.60 s ($C^{2'}$), 123.63 d (C^4), 125.83 s (C^3), 129.24 s ($C^{3'}$), 144.53 d (C^5), 146.93 s and 150.84 s (C^{8a}, C^{9a}), 156.30 s (C^2), 158.66 s (C^7), 163.16 s ($C^{8'}$), 165.41 s and 169.78 s (C=O). Found, %: C 57.46; H 4.89; N 5.09; S 6.67. $C_{24}H_{22}N_2O_8S$. Calculated, %: C 57.82; H 4.45; N 5.62; S 6.43.

(6*R*,7*R*)-7-(2-Isopropyl-7-oxo-7*H*-furo[3,2-*g*]-chromen-3-ylamino)-3-methyl-8-oxo-5-thia-1-azabicyclo[4.2.0]oct-2-ene-2-carboxylic acid (XXII). Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 214 mg (1 mmol) of 7-amino-(deacetoxy)cephalosporanic acid (**XIX**), 4.4 mg (4 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (1.3 equiv) of triethylamine were added under argon, and the mixture was heated for 6 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel. Yield 95 mg (42%), mp 181–182°C (from diethyl ether), $[\alpha]_D^{20}$ = –180.0° (*c* = 0.1, H_2O–EtOH, 2:1). IR spectrum, ν, cm^{-1}: 3435, 3190, 3090, 3062, 3048, 2980, 2937, 1777, 1732, 1716, 1633, 1579, 1501, 1470, 1454, 1388, 1348, 1321, 1286, 1250, 1211, 1198, 1140, 1115, 1068, 1047, 902, 869, 835, 810, 780, 765, 745, 698, 648, 626, 602. UV spectrum (EtOH), λ_{max}, nm (logε): 200 (4.30), 221 (4.19), 251 (4.41), 295 (3.94), 306 (3.92), 342 (4.03), 351 (4.04). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 1.31 d [6H, (C**H**$_3$)$_2$CH, *J* = 7.0 Hz], 1.96 s (3H, CH_3), 3.23 m [1H, $(CH_3)_2$C**H**], 3.58 m (2H, 4′-H), 4.69 d.d (1H, 6′-H, *J* = 5.0, 1.8 Hz), 4.95 m (1H, 7′-H), 6.46 d (1H, 6-H, *J* = 9.8 Hz), 7.77 s (1H, 9-H), 7.87 s (1H, 4-H), 8.20 d (1H, 5-H, *J* = 9.8 Hz). ^{13}C NMR spectrum

(DMSO-d_6), δ_C, ppm: 19.77 q (CH_3), 20.02 q [(**C**H_3)$_2$CH], 25.71 d [**C**H(CH_3)$_2$], 29.07 t ($C^{4'}$), 57.72 d ($C^{7'}$), 62.30 d ($C^{6'}$), 100.41 d (C^9), 107.83 s (C^{4a}), 115.31 d (C^6), 115.95 s (C^{3a}), 118.23 s ($C^{2'}$), 123.75 d (C^4), 124.50 s (C^3), 126.16 s ($C^{3'}$), 144.43 d (C^5), 152.17 s and 152.53 s (C^{8a}, C^{9a}), 156.63 s (C^2), 159.81 s (C^7), 165.57 s and 169.41 s (C=O). Found, %: C 59.32; H 4.89; N 5.93; S 7.00. $C_{22}H_{20}N_2O_6S$. Calculated, %: C 59.99; H 4.58; N 6.36; S 7.28.

7-Amino(deacetoxy)cephalosporanic acid methyl ester (XX). Acid **XIX**, 300 mg (1.4 mmol), was dispersed in a mixture of diethyl ether with methylene chloride (2:3), 20 ml of a solution of diazomethane in diethyl ether (prepared from 1.5 g of nitrosomethylurea according to [22]) was added dropwise under stirring, and the mixture was left to stand for 16 h. The precipitate of unreacted acid **XIX** (130 mg) was filtered off, the filtrate was evaporated, the residue was treated with diethyl ether, and the precipitate was filtered off. Yield 140 mg, mp 210–211°C, $[\alpha]_D^{20}$ = –105.8° (*c* = 1.0, $CHCl_3$). IR spectrum, ν, cm^{-1}: 3424, 2960, 2927, 1783, 1741, 1672, 1508, 1457, 1438, 1369, 1328, 1294, 1213, 1159, 1133, 755. UV spectrum (EtOH), λ_{max}, nm (log ε): 204 (2.74), 245 (2.80), 296 (2,41), 322 (2.42). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.93 s (3H, CH_3), 3.06 d and 3.20 d (1H each, 4-H, *J* = 18.2 Hz), 3.64 s (3H, OCH_3), 4.52 m (1H, 6-H), 4.71 m (2H, NH_2), 4.89 d (1H, 7-H, *J* = 4.9 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 18.77 q (CH_3), 26.41 t (C^4), 52.67 q (OCH_3), 60.36 d (C^7), 63.71 d (C^6), 124.32 s (C^2), 135.20 s (C^3), 163.79 s (C=O), 168.72 s (C=O).

Methyl (6*R*,7*R*)-7-(2-isopropyl-7-oxo-7*H*-furo-[3,2-*g*]chromen-3-ylamino)-3-methyl-8-oxo-5-thia-1-azabicyclo[4.2.0]oct-2-ene-2-carboxylate (XXIII). Compound **I**, 200 mg (0.5 mmol), was dissolved in 3 ml of anhydrous DMF, 228 mg (1 mmol) of ester **XX**, 4.4 mg (4 mol %) of palladium(II) acetate, 34 mg (8 mol %) of BINAP, and 0.07 ml (1.3 equiv) of triethylamine were added under argon, and the mixture was heated for 6 h at 115°C until initial compound **I** disappeared (TLC) and evaporated. The residue was subjected to column chromatography on silica gel. Yield 86 mg (38%), mp 141–142°C (from diethyl ether), $[\alpha]_D^{20}$ = –67.2° (*c* = 0.5, $CHCl_3$). IR spectrum, ν, cm^{-1}: 3356, 3190, 3062, 2962, 2923, 2852, 1766, 1730, 1706, 1625, 1573, 1483, 1465, 1440, 1390, 1325, 1290, 1186, 1141, 1103, 943, 910, 825, 744, 698. UV spectrum (EtOH), λ_{max}, nm (log ε): 202 (4.45), 222 (4.31), 253 (4.32), 298 (3.97), 309 (3.96), 336 (3.99). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.31 d [6H, (C**H**$_3$)$_2$CH, *J* = 7 Hz], 2.03 s (3H, CH_3), 3.16 m (1H, NH), 3.23 m [1H, (CH_3)$_2$C**H**], 3.55 d and 3.75 d (1H each, 4′-H, *J* = 18.0 Hz), 3.91 s (3H, OCH_3), 4.63 d (1H, 6′-H, *J* = 4.6 Hz), 4.88 m (1H, 7′-H), 6.36 d (1H, 6-H, *J* = 9.8 Hz), 7.36 s (1H, 9-H), 7.54 s (1H, 4-H), 7.79 d (1H, 5-H, *J* = 9.8 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 19.27 q (CH_3), 20.08 q [(**C**H_3)$_2$CH], 25.78 d [**C**H(CH_3)$_2$], 29.49 t ($C^{4'}$), 59.02 d ($C^{7'}$), 51.04 q (OCH_3), 63.37 d ($C^{6'}$), 100.45 d (C^9), 109.51 s (C^{4a}), 115.21 d (C^6), 116.58 s (C^{3a}), 118.93 d (C^4), 119.99 s ($C^{2'}$), 125.94 s (C^3), 136.53 s ($C^{3'}$), 143.80 d (C^5), 151.98 s and 152.92 s (C^{8a}, ^{9a}), 156.91 s (C^2), 160.73 s (C^7), 166.43 s ($C^{8'}$), 172.56 s (C=O). Found, %: C 59.88; H 4.75; N 5.81; S 6.90. $C_{23}H_{22}N_2O_6S$. Calculated, %: C 60.78; H 4.88; N 6.16; S 7.06.

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